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The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
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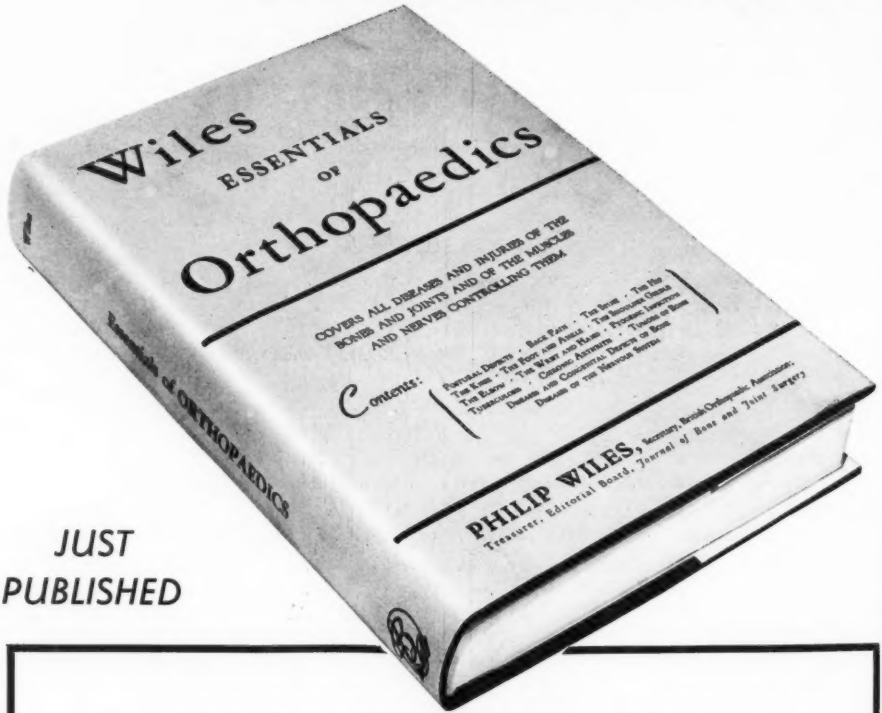
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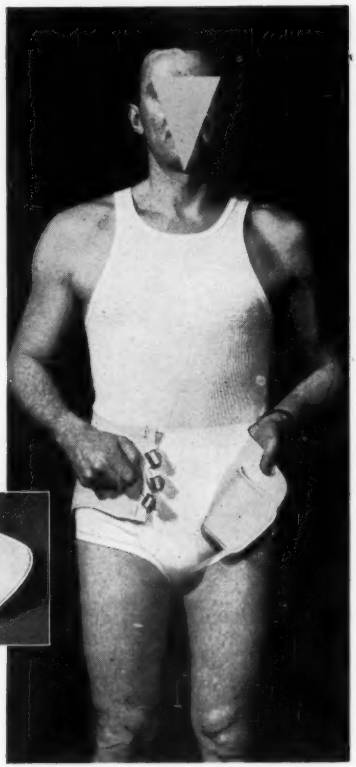

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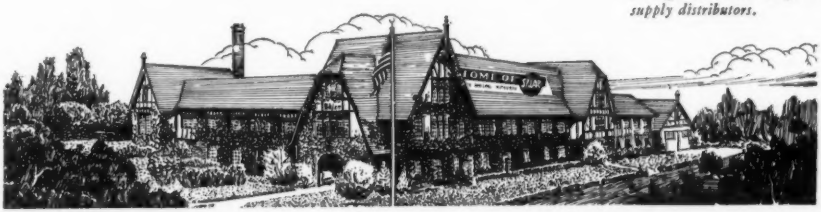

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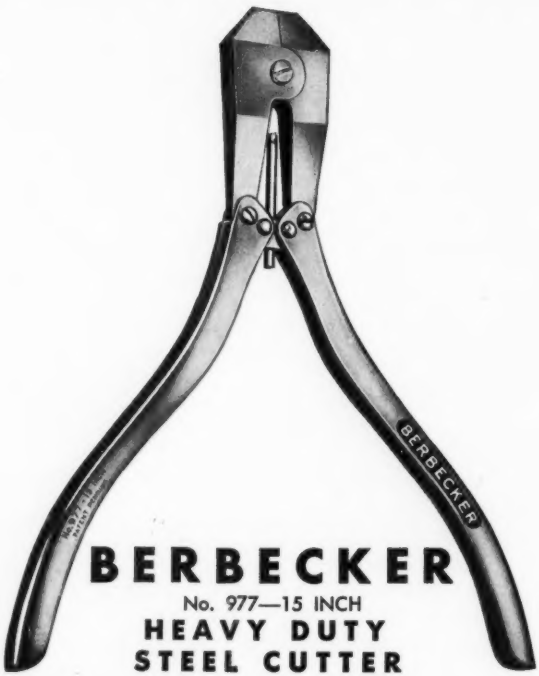

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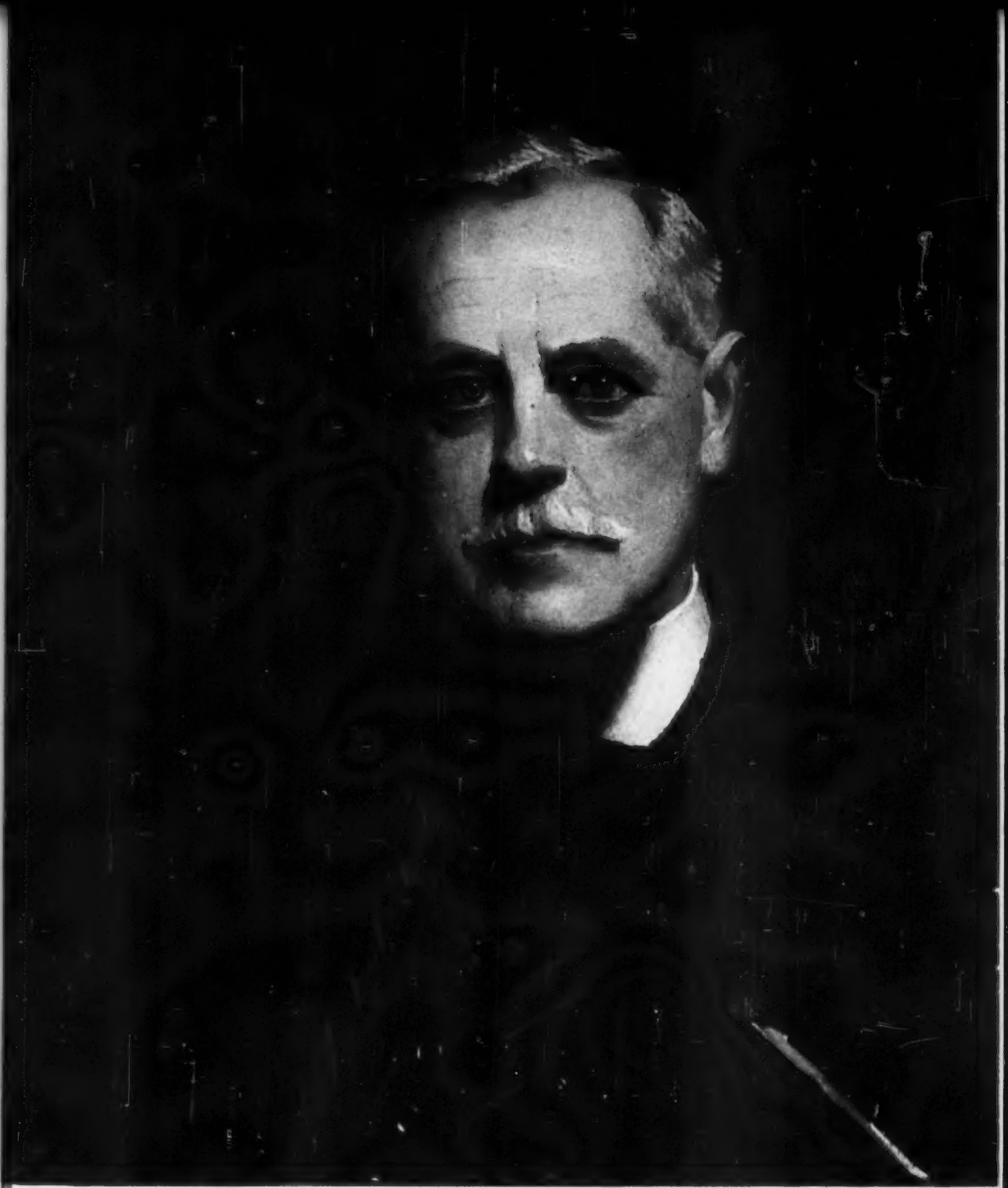

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COURTESY, JOHNS HOPKINS HOSPITAL

William Holland Wilmer

1863-1936

A graduate of University of Virginia, Dr. Wilmer studied at New York Polyclinic and various European hospitals. Beginning the practice of ophthalmology in New York in 1906, he became professor of ophthalmology at Georgetown University. In 1925 he went to Johns Hopkins University as professor and ophthalmologist-in-chief to Johns Hopkins Hospital.

The Wilmer Institute, of which he was Director, was created as a tribute by friends and patients. Dr. Wilmer served as an overseas medical officer during the first World War and was a Brigadier General in the Medical Reserve Corps. He was a founder of the American College of Surgeons and contributed much to the literature on ophthalmology.

From the Series, Great American Surgeons, Published By

ETHICON SUTURE LABORATORIES, DIVISION OF JOHNSON & JOHNSON, NEW BRUNSWICK, N. J.

Chicago, Ill.—Photograph in Ethicon Suture Laboratories, showing ribbons of surgical gut being inspected just prior to immersion in chrome bath. After chromicization several ribbons are spun into a completed suture strand. Tru-chromicizing before spinning, an exclusive Ethicon process, assures uniform chrome disposition, resulting in uniform digestion by tissue enzymes.

Why you get a better suture

WITH ETHICON'S TRU-CHROMICIZING PROCESS

The fate of the absorbable suture after implantation and wound closure, and its reactions in the host, are the ultimate test of the suture's quality and dependability.

Today chromicized gut is widely used because of its resistance to digestion until healing is accomplished. In this aspect, the chromic suture must possess these attributes:

1. Sufficient chrome content to withstand premature digestion.

2. Chrome concentration must not be so excessive that fragments of the suture resist digestion and persist in tissue. This condition frequently leads to knot extrusion.

In order to obtain a product having the highest possible degree of uniformity, Ethicon chromicizes raw gut strands in the ribbon stage. This more meticulous process was named Tru-chromicizing. The alternative method, used by others, called surface-chromicizing, involves the dipping of the finished, spun and dried suture strand in a chrome bath. These are the results of the two methods:

Surface-Chromicizing

In enzyme solution, the core of most surface-chromicized gut digests readily, leaving a hollow cylinder which separates into ribbons.

This cylinder may be excessively resistant to enzyme action and remain as an undigested foreign body indefinitely.

Tru-Chromicizing

Ethicon Tru-chromicized gut exhibits uniform enzyme resistance throughout digestion. It digests from the surface inward, and retains its integrity as a unified suture until dissolution approaches completion.

Total digestion eliminates the danger of knot extrusions and sterile stitch abscesses.

What Tru-Chromicizing Means To You

1. Less interference with healing through minimized foreign body reaction.

2. High tensile strength of suture retained for the healing period, followed by complete absorption.

3. Uniformity in those physical and physiologic characteristics essential to accurate surgical technic.

SURFACE-CHROMICIZING*

When gut is chromicized after strands are spun and dried, chrome concentration is very high in surface layers and relatively low in the core. Inner core is digested rapidly—the highly chromicized periphery survives for prolonged periods.

ETHICON TRU-CHROMICIZING

Individual ribbons of gut are soaked in chrome bath before *they are spun into strand, permitting uniform deposition of chrome. The strand thus has the same chrome content from periphery to center.*

ETHICON
Sutures

***To illustrate this comparison, small laboratory trays are used. In commercial production, surface-chromicizing is done under tension. Both processes are performed in large vats.**

Non-Absorbable Sutures of Choice

NYLON – Ethicon's Black Braided Nylon has high tensile strength, ties readily, and is gauged according to U.S.P. sizes.

Ethicon Nylon is a specially processed strand which fully meets the surgeon's requirements for a non-absorbable suture. It is moisture and serum proof.

COTTON—Ethicon Cotton, U.S.P., is 10% to 30% stronger than ordinary cotton. Specially prepared from imported 100% Egyptian long staple fiber.

Ethicon cotton is free from lint and irregularities. No harsh fillers or harmful dyes.

If you have a preference for cotton, try Ethicon Twisted Cotton.

SILK—You get intrinsic strength and minimal tissue reaction with Ethicon Tru-Formed Black Braided Silk Sutures.

Ethicon Silk forms smooth, firm knots, has minimal adherence to tissue. Non-capillary, serum-proof, non-toxic, strictly U.S.P. gauge.

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ETHICON
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Suture Laboratories at New Brunswick, N. J.; Chicago, Ill.; Brazil; Argentina; Scotland; Australia

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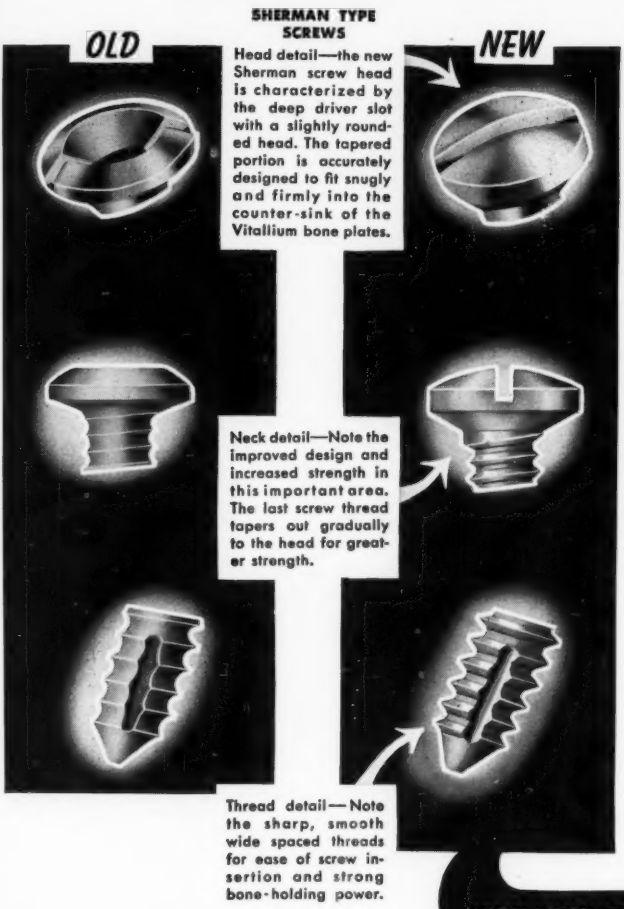

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Head detail—the new Sherman screw head is characterized by the deep driver slot with a slightly rounded head. The tapered portion is accurately designed to fit snugly and firmly into the counter-sink of the Vitallium bone plates.

Neck detail—Note the improved design and increased strength in this important area. The last screw thread tapers out gradually to the head for greater strength.

Thread detail—Note the sharp, smooth wide spaced threads for ease of screw insertion and strong bone-holding power.

Types of Vitallium Surgical Screws available:
Sherman-type, coarse threaded; Phillips recessed-head type; Wood types; Large Venable types; Transfixion screws; Finger plate and skull plate screws.

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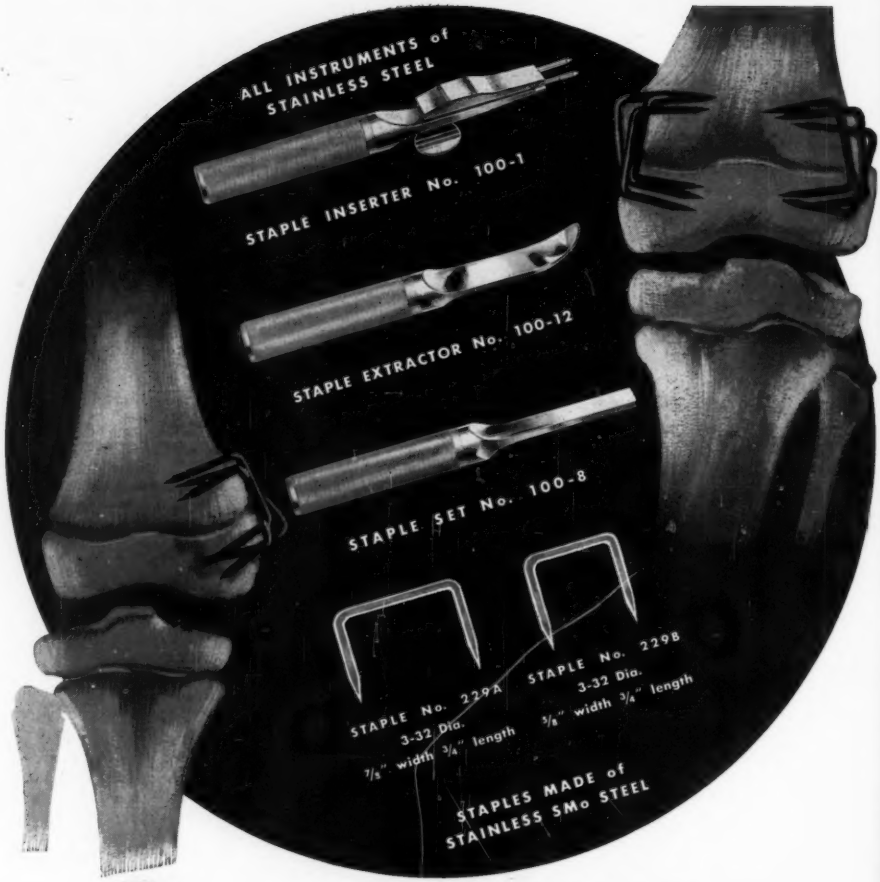

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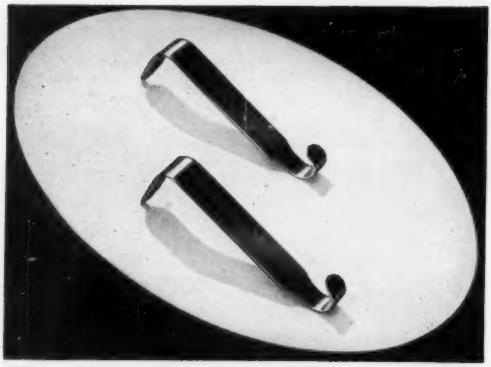

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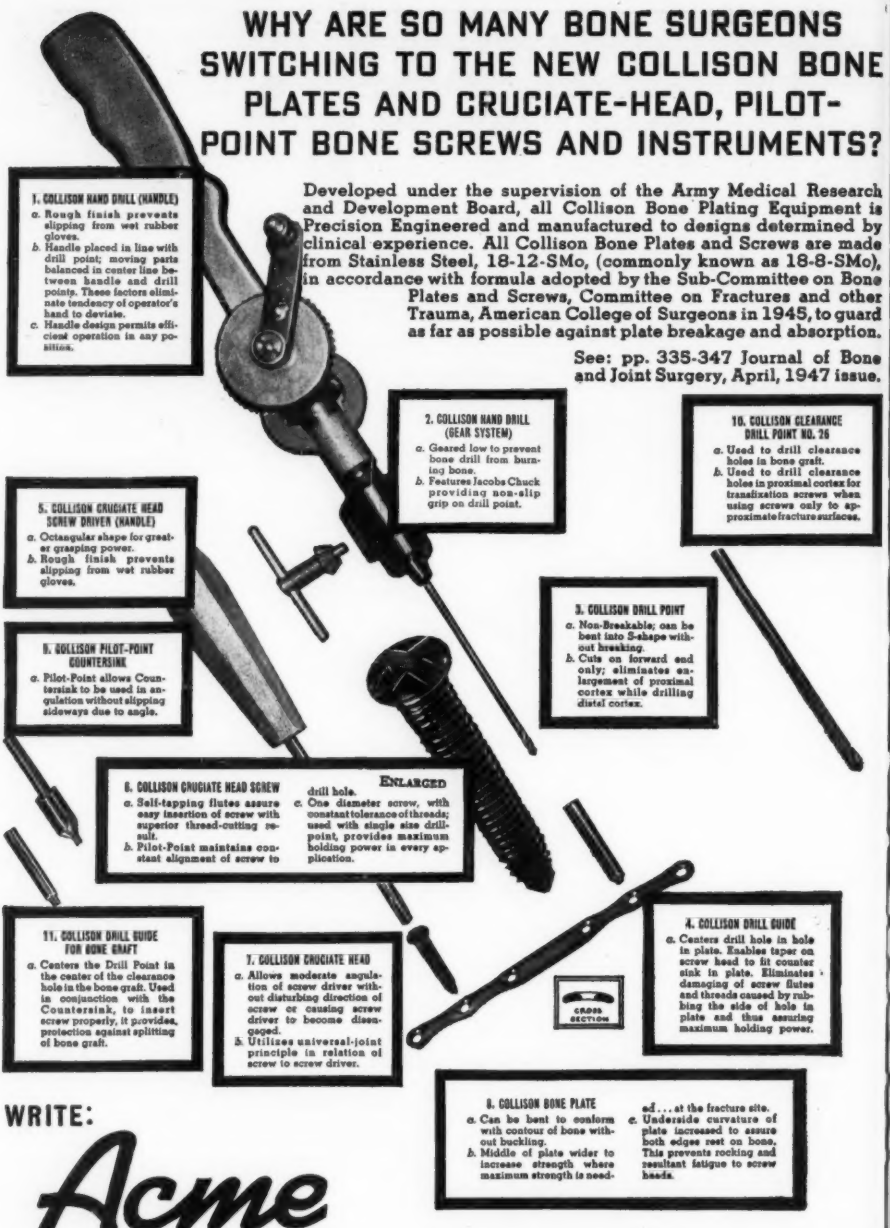
See: pp. 335-347 Journal of Bone and Joint Surgery, April, 1947 issue.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a. Rough finish prevents slipping from wet rubber gloves.
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b. Features Jacobs Chuck providing non-slip grip on drill point.
10. COLLISON CLEARANCE DRILL POINT NO. 26
a. Used to drill clearance holes in bone graft.
b. Used to drill clearance holes in proximal cortex for transfixation screws when using screws only to approximate fracture surfaces.
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11. COLLISON DRILL GUIDE FOR BONE GRAFT
a. Centers the Drill Point in the center of the clearance hole in the bone graft. Used in conjunction with the Countersink, to insert screw properly, it provides protection against splitting of bone graft.
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a. Allows moderate angulation of screw driver without disturbing direction of screw or causing screw driver to become disengaged.
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CROSS SECTION
4. COLLISON DRILL GUIDE
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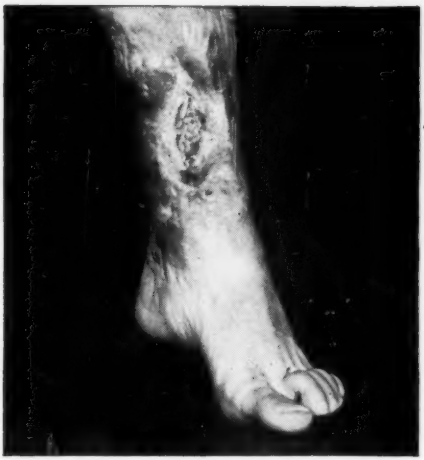

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*Boehme, E. J.	The Treatment of Chronic Leg Ulcers	The Lahey Clinic Bulletin, 4:242 (1946)
Bowers, Warner F.	Chlorophyll in Wound Healing and Suppurative Disease	Amer. J. Surgery. LXXIII:37 (1947)
Cady, Jos. B. and Morgan, W. S.	Treatment of Chronic Ulcers with Chlorophyll	Amer. J. Surgery. LXXV:4 (1948)
Johnson, Harold M.	Dermatologic evaluation . . .	Arch. Dermat. & Syph. 57:348 (1948)
Langley, W. D. and Morgan, W. S.	Chlorophyll in the Treatment of Dermatoses	Penn. Med. Journal. Vol. 51; No. 1 (1948)
Rafsky, Henry A. and Kreiger, Charles I.	Treatment of Intestinal Diseases with sols. of w. s. Chlorophyll	Rev. Gastroent Vol. 15:549 (1948)

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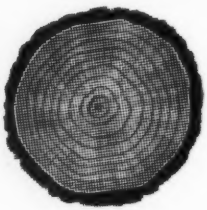

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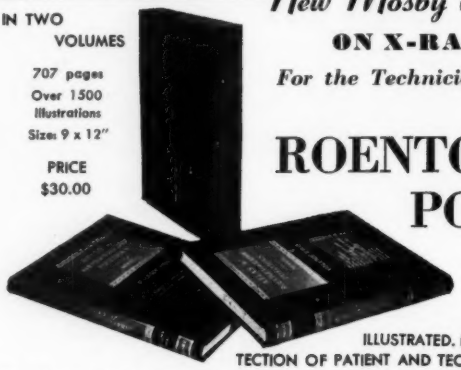

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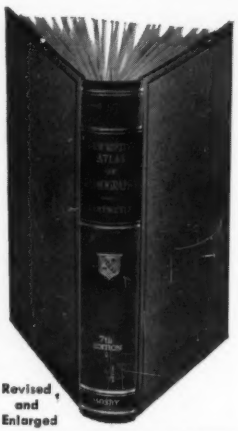

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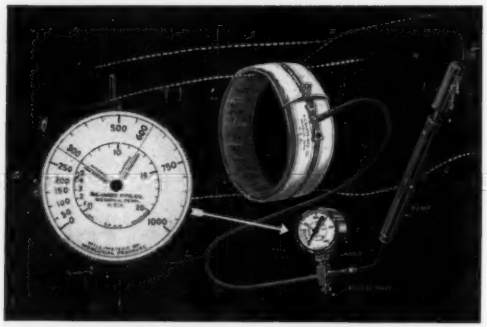

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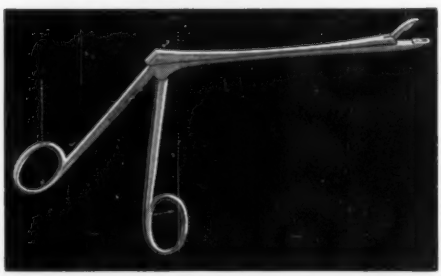

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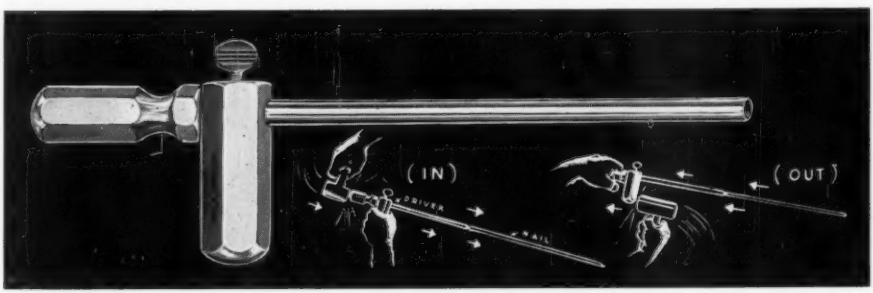

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VOL. 31-A, NO. 4 OCTOBER 1949

The Journal of
Bone and Joint Surgery

American Volume

THE INFLUENCE OF THE CONTACT-COMPRESSION FACTOR ON OSTEOGENESIS IN SURGICAL FRACTURES *

BY G. W. N. EGGERS, M.D., THOMAS O. SHINDLER, M.D.,
AND CHARLES M. POMERAT, PH.D., GALVESTON, TEXAS

From the Department of Orthopaedic Surgery and the Department of Anatomy, University of Texas School of Medicine, Galveston

The results of physical forces on osseous structures have been recorded for a long time by observers of morphological characteristics. That bone conforms architecturally to new stress and strain created by deformity and trauma was expressed in 1892 by Julius Wolff, who advanced the theory that every change in the form and function of a bone or in its function alone is followed by certain definite changes in its internal architecture and equally definite secondary alterations in its mathematical laws. The principle expressed has since been known as Wolff's law; but, because of the physiological variables, Wolff could never reduce the observation to mathematical accuracy[1].

Hugh Owen Thomas expressed his observations in 1883: "The presence of vitality in the body is a factor in aiding us to mechanically correct even mechanical defects; as eccentric forms, that cannot be altered in the dead body, without rupture or fracture, can, during life, be altered by mechanical influence, as time and physiological action will commode the part to the direction of the employed force."

In 1929, Fell and Robison showed, by explanting a segment of embryonic femoral cartilage, that the femur would develop on the same general lines as in the normal limb. Thus, the structures possess an inherent factor of configuration.

These clinical observations and experimental findings are not in conflict and suggest that a bone, although inherently designed, may respond later with architectural changes.

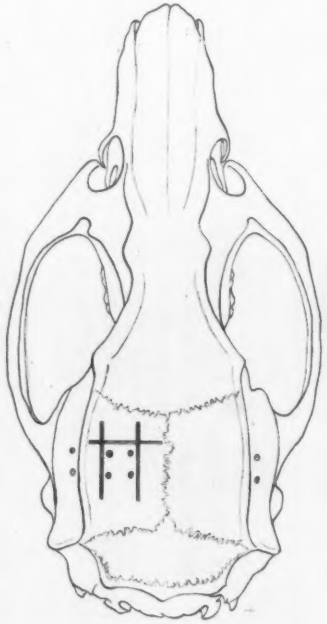
Glücksmann, in 1938, showed an effect of compression *in vitro;* he subjected endosteal cultures to pressure by placing them in intercostal muscle between two growing ribs. Oriented structures were produced in unoriented bone tissue.

To determine the influence of a compression force in osseous repair and to test its consistency were the purposes of the experimental work to be presented. To create a controlled investigative condition which involves so many physiological variables presented almost insurmountable difficulties. Study was made of the femora and tibiae in dogs and in rats, but the data were discarded since accurate controls could not be instituted.

The problem of securing living bone free from compression, tension, or muscular influences, yet adequate for the application of experimental devices to produce a controllable artificial force, was resolved by the selection of the parietal bone of adult rats. It was considered that this selection would provide a highly critical test of the hypothesis suggested, since membrane bone is notably poor in its osteogenetic response[9].

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1949.

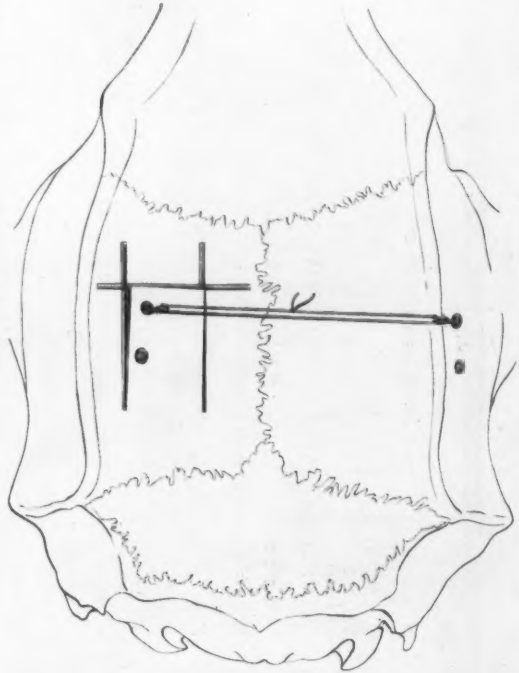
RAT SKULL SHOWING OPERATIVE SITE IN LEFT PARIETAL BONE



Drill holes (represented by circles) indicate various points where compression sutures were inserted

FIG. 1

ENLARGEMENT OF OPERATIVE SITE SHOWING HOW COMPRESSION WAS APPLIED MEDIALLY



Alternate compression point indicated by extra drill holes

FIG. 2

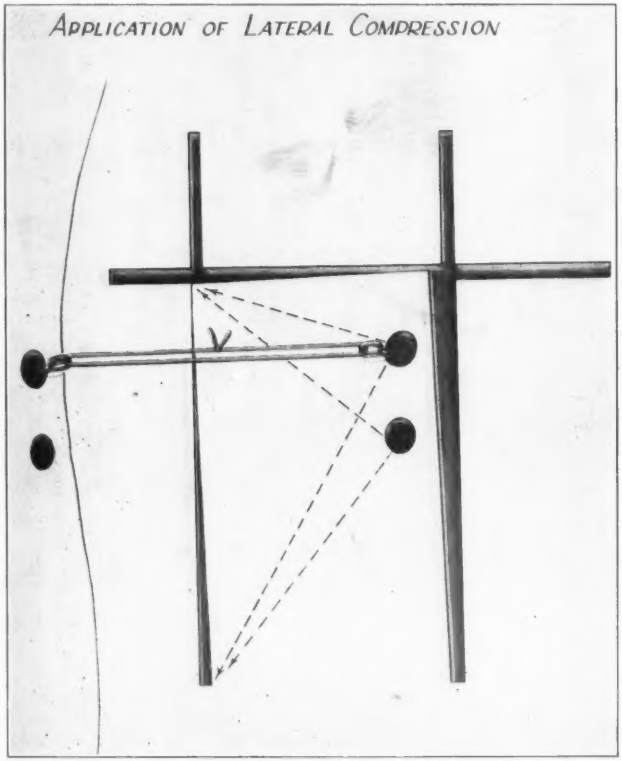


FIG. 3

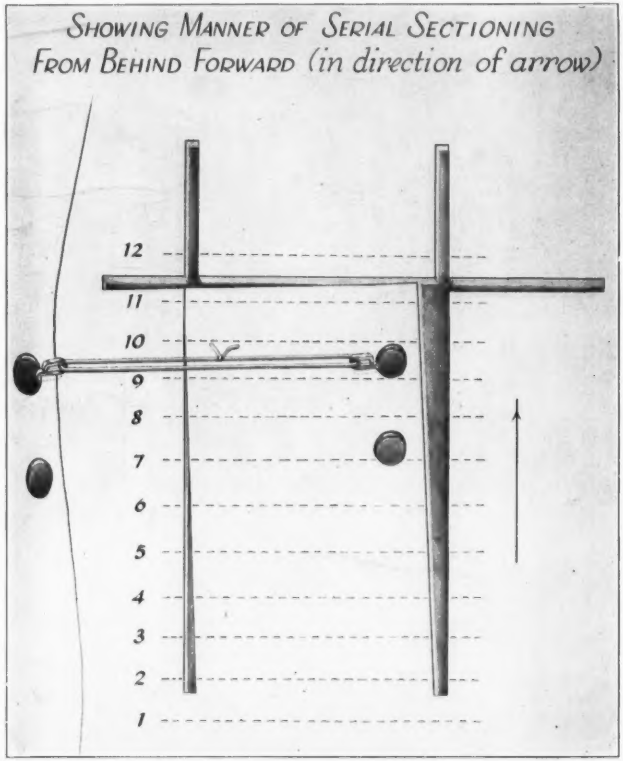


FIG. 4

Fig. 3: Application of lateral compression. Representative vector forces are indicated by arrows.
Fig. 4: Manner of serial sectioning.

TECHNIQUE

The experimental operative procedures were performed under inhalation ether anaesthesia with three instrument-sterilization techniques,—that is, without antisepsis, with alcohol antisepsis, and with heat antisepsis. After longitudinal incision of the skin and superficial fascia over the middle of the skull of mature white rats, the procedure consisted in making a three-sided flap in the left parietal bone (Fig. 1) with a rotary saw, 150 micra thick and 1.38 centimeters in diameter. One cut was made parallel to the sagittal suture, another 2 to 3 millimeters lateral to this, and a third connecting the two anteriorly. The flap with its periosteum and blood supply remained attached behind, providing a point of fixed anchorage.

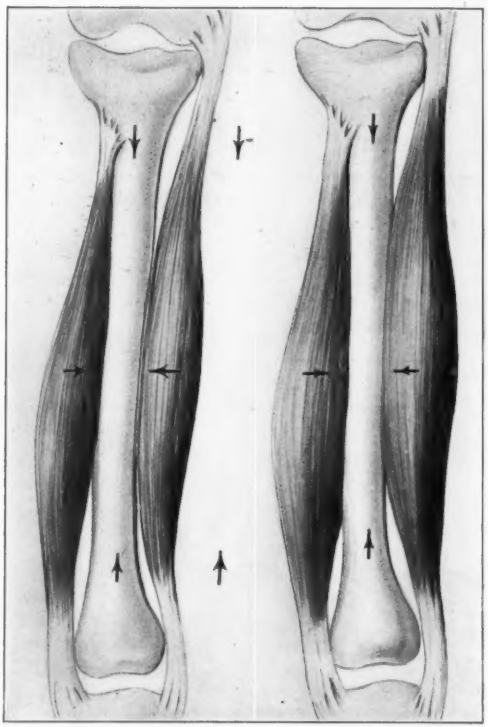


FIG. 5-A FIG. 5-B

Diagrammatic representation of longitudinal and transverse muscular compression forces on a long bone.
Fig. 5-A: Muscle tone exerts a more or less constant factor.
Fig. 5-B: Voluntary contraction increases the transverse and longitudinal compression factor.

In the application of lateral compression, a small hole was drilled in the flap anteromedially and another laterally at the same level through the left temporal bone, after the temporal muscle had been reflected. Cotton thread (No. 8), put through these holes extradurally and extracranially, was tied tightly so that the bone flap turned slightly laterally, approximating with some compression the bony margins of the lateral cut and leaving the margins of the medial cut separated by not more than 360 micra at the anterior pole. The skin and superficial fascia were closed with interrupted cotton sutures.

In the application of medial compression, the three-sided flap was made in a similar manner, but a hole was drilled in the anterolateral aspect of the flap and the corresponding drill hole was made in the right temporal bone. A small stainless-steel wire hook was placed into each of these two holes, and the two hooks were connected with a rubber band under tension (Fig. 2). The skin and superficial fascia were closed over this appliance. By varying the points of the drill holes in the bone flap and the corresponding ones in the temporal bones, the distribution of the total force applied could be varied (Fig. 3).

At intervals following the operation, the animals were sacrificed; the appliances were removed; and the entire flat surface of the calvarium of each rat was excised circularly and placed in 10 per cent. Zenker-formalin solution, followed by decalcification in 2 per cent. hydrochloric acid and embedding in paraffin. The skull of each animal was serially cross-sectioned from behind forward (Fig. 4), making a combined total of more than 12,000 sections which were observed after staining with hematoxylin and eosin.

Eighteen animals were successfully operated upon in this experiment. This included

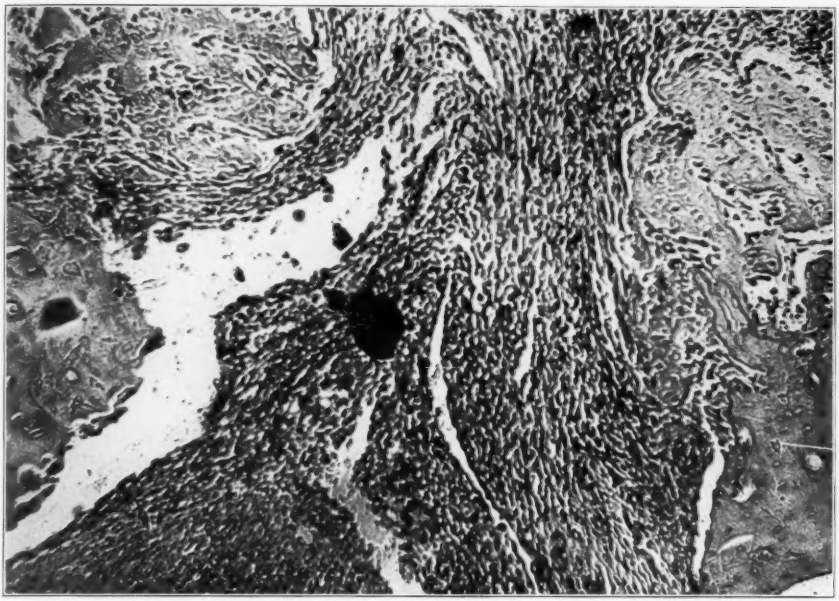


FIG. 6

Osteogenesis of endochondral bone in femur of an adult rat (× 150).

thirteen in which the contact-compression factor was applied and five in which it was omitted. Sections from ten animals are included in the illustrations. Of the eleven animals in which the contact-compression factor was applied and which were sacrificed after the fifteenth postoperative day, ten showed a favorable response to the force applied. None of the animals not subjected to the contact-compression factor showed any significant osteogenetic activity.

Discussion of Technique

Each specimen of animal skull presented a field of study in which there was an area of static flap control (Fig. 4,*12*); a movable flap, to the margin of which the contact-compression factor could be applied (Fig. 4,*1* to *11*); the opposite, non-compressed control flap margin; and an undisturbed skull margin (Fig. 4, arrow).

The experimental technique described furnished material which was placed under mechanical stress, applied on a margin of choice. One free margin of the bone flap was compressed anteriorly; but, proceeding posteriorly, the degree of compression decreased, and finally there was no contact at all. Thus, material with contact and compression, with contact and excessive pressure, and with compression and no contact could be observed.

Since it was not possible experimentally to ensure contact without some compression, and since it was shown in these experiments that compression could be produced without contact, the authors selected the term "contact-compression factor". This factor is, therefore, the combination of contact and the force to promote contact, exerted on bone structures for which osseous union or osteogenesis is desired.

The contact-compression factor is constantly considered in the work on osseous structures with which surgeons and orthopaedic workers are associated. In dealing with these problems, the factor is unwittingly utilized, purposely violated, or surgically created. It is reasonable to assume that contact demands compression to some degree. It is also possible

that a compression force may be exerted throughout a bony structure without contact of the affected margin.

The contact-compression factor consists of two parts: (1) contact of surfaces under compression; and (2) the compression force, endeavoring to bring into actual contact fracture surfaces which are only opposed. In a fracture the compression may consist of either of two forces,—internal or external; each is exerted on the fracture surfaces.

The internal force is physiological and is created by the muscles. The force is composed of two parts,—the muscle tone and voluntary muscle contraction. The muscular forces are effective in many planes, as in the vertebrae or pelvis; but two directions, the longitudinal and transverse, are more dominant as applied to long bones. The transverse pressure is exerted by the mass of the muscle structure, especially in the voluntary contraction which increases the diameter of the muscle (Figs. 5-A and 5-B). This is particularly effective, because of the fact that the musculature is practically always contained within a fascial sheath of some type or degree. The longitudinal force is due to muscle tone and is greatly influenced by muscle contractions. The certain fact of all muscular forces is that they are variable in proportion to the muscular activity.

The external contact-compression force is due to non-physiological forces, such as gravity, weight-bearing, and surgical methods, which may follow an anatomical pattern.

Fracture reduction of opposing surfaces results in partial contact and much approximation. Surgical procedures, such as arthrodesis and grafting of bone, cannot be expected to furnish perfect contact, but present a relatively large surface approximation. Thus, the securing of bony union or osteogenesis is dependent on the osteogenetic effort of the involved bone surfaces. As indicated in these experiments, the influence of the contact-compression factor is clinically important[2, 3, 5, 8].

RESULTS

In the interpretation of the experimental findings, the authors were aware of many

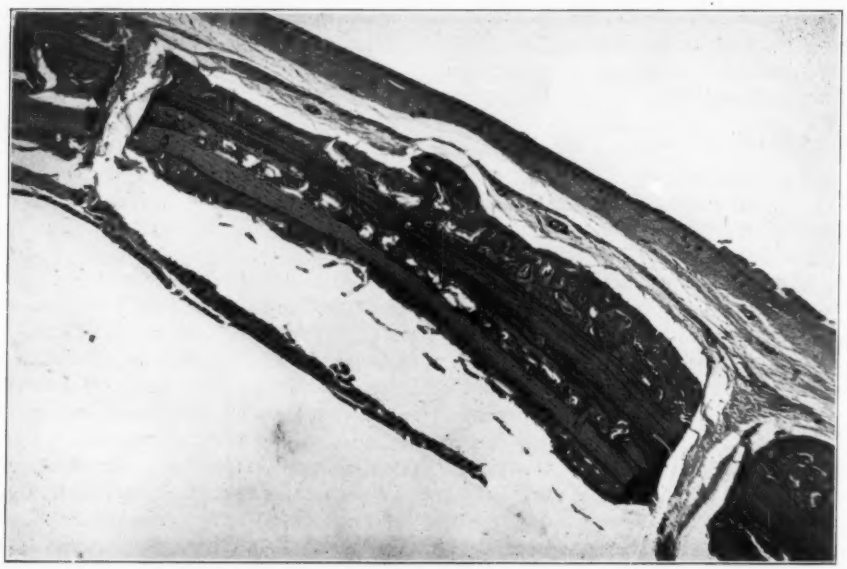


FIG. 7-A

Area 12, sixteen days (× 40). No contact-compression factor was applied to this area of flap. No effort at union of fracture margins is evident. (This is the control area of Figs. 8-A, 8-B, and 8-C.)

FIG. 7-B

Lateral cut (× 150). There is no purposeful osteogenesis for union.

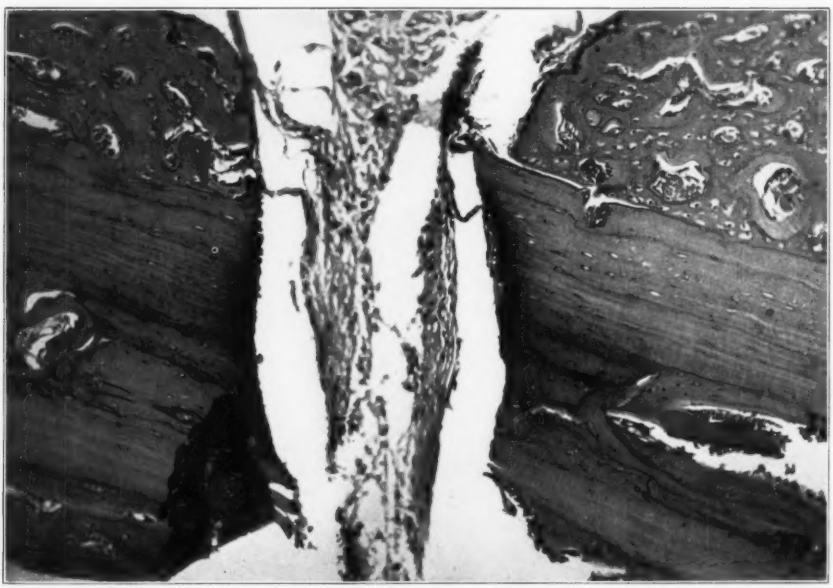


FIG. 7-C

Medial cut (× 150). There is no purposeful osteogenesis for union.

conditions affecting osteogenesis and, without altering or analyzing them, have attempted to keep the physiology of experimental fields of the control and of the affected part vir-

tually identical by conducting both in the same animal within a limited transverse physical space of about 2,500 micra. Thus, in the experiments, the control margin can be seen simultaneously in the low-power microscopic field with the experimental margin of the bone studied. It is reasonable to assume that no great physiological variation would be present in such close proximity.

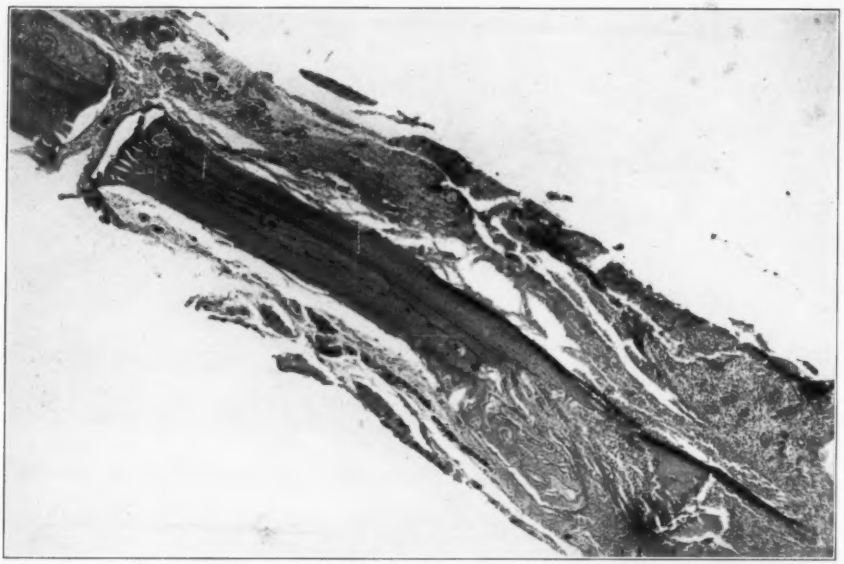


FIG. 8-A

Area 11, sixteen days. Medial contact-compression factor was applied. There is osteogenetic activity of medial margin (× 40).

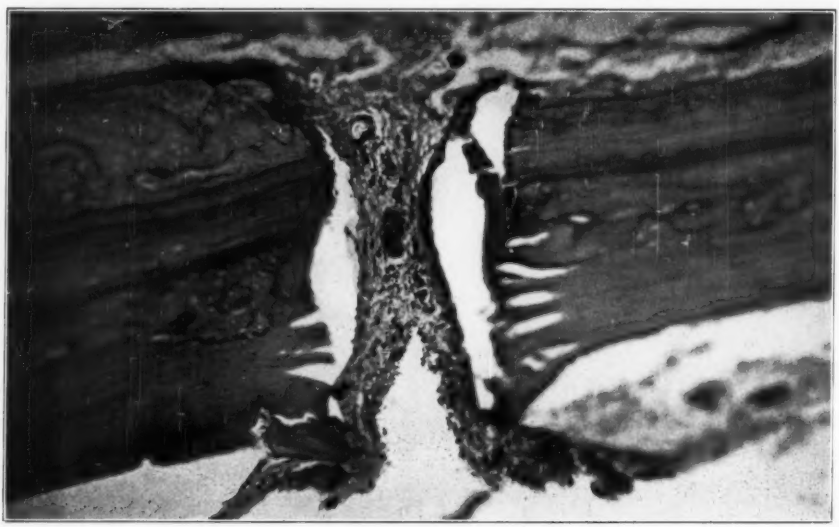


FIG. 8-B

Lateral cut (× 150). Fibrous tissue is present in fracture interval.

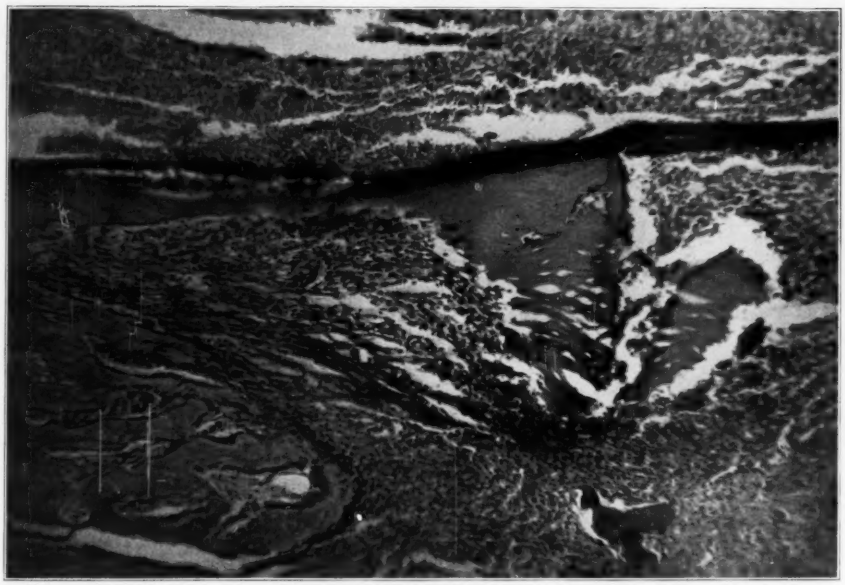


FIG. 8-C

Showing osteogenesis of membranous bone in adult rat. Medial cut (× 150). Osteogenetic activity, fragmentation, and osteoblastic invasion of reticular network may be noted. The osteogenetic activity is identical with that in Fig. 6.

The basic osteogenesis of bone is the same in membranous and endochondral bone (Figs. 6 and 8-C). Each presents primarily a reticulo-collagenous network, followed by

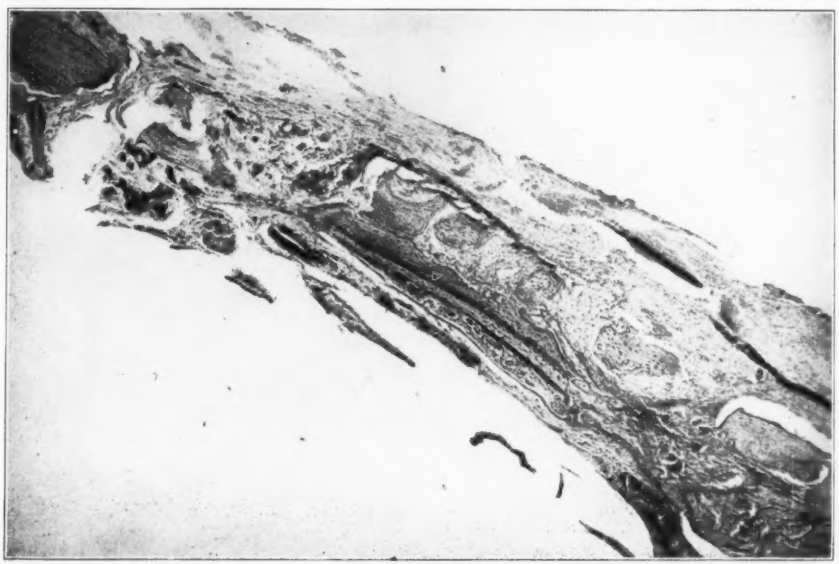


FIG. 9-A

Area 7, sixteen days. Medial contact-compression factor was applied. Section made through edge of compression hole (× 40). Note pressure necrosis due to excess pressure on lateral margin. Osseous activity occurs on medial side.

osteoblastic invasion and deposition of calcium salts. Cartilage may be seen in membranous as well as endochondral bone, as observed by Pritchard.

The figures of the microscopic studies are oriented so that uniformly the lateral border

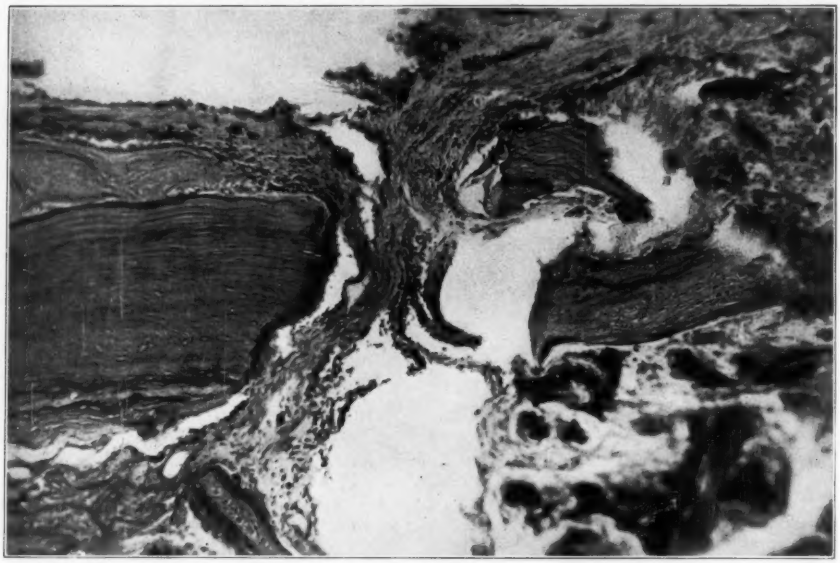


FIG. 9-B

Lateral cut (× 150). Lateral flap margin shows necrosis and fragmentation.

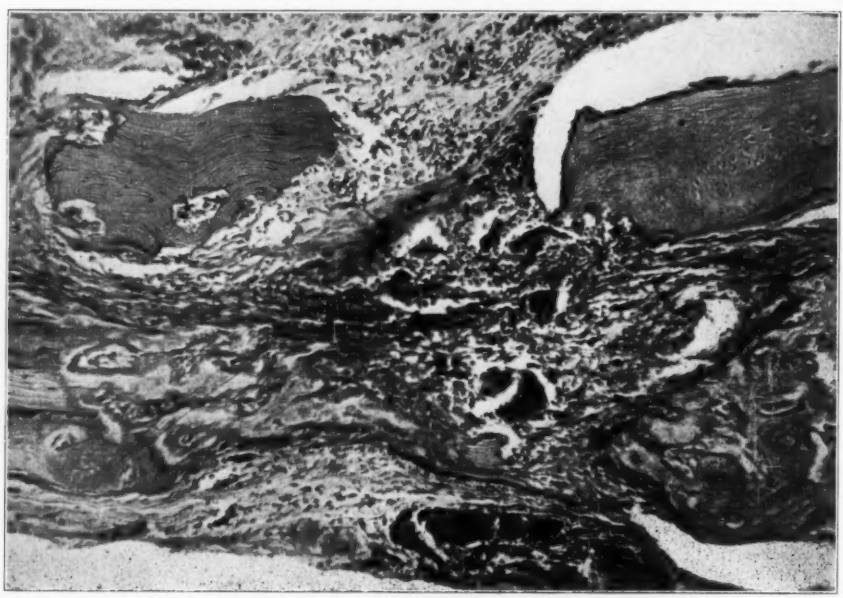


FIG. 9-C

Medial cut (× 150). There is active osteogenesis in both margins of fracture interval.

of the skull flap is on the reader's left, the medial side on the right, the cutaneous portion at the top, and the dural surface below. The gap due to the saw cut is usually obvious, and each section is shown in a low-power (× 40) and a higher-power magnification (× 150) of each surgical fracture. The age in days of each section indicates the number of days after operation at which the animal was sacrificed. The area number indicates the position on the bone flap from which that section was taken (Fig. 4).

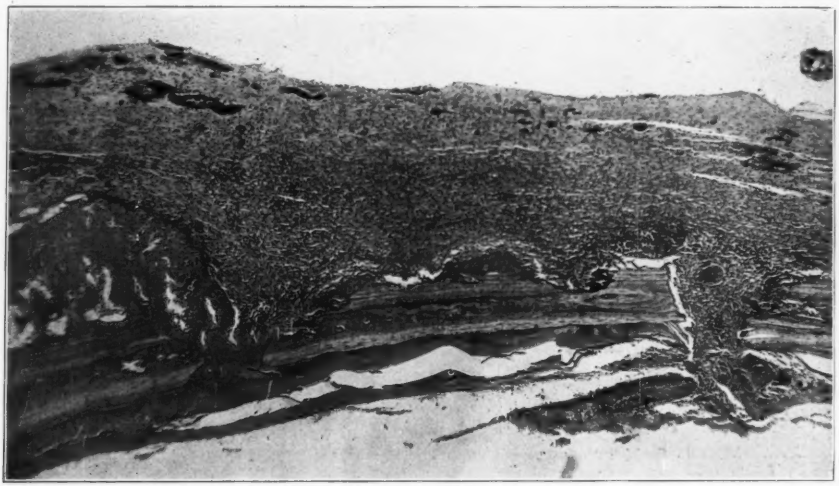


FIG. 10-A

Area 6, seventeen days (× 40). Lateral contact-compression factor was applied. Contrast the osseous union on lateral aspect with fibrous tissue in fracture gap on medial side.

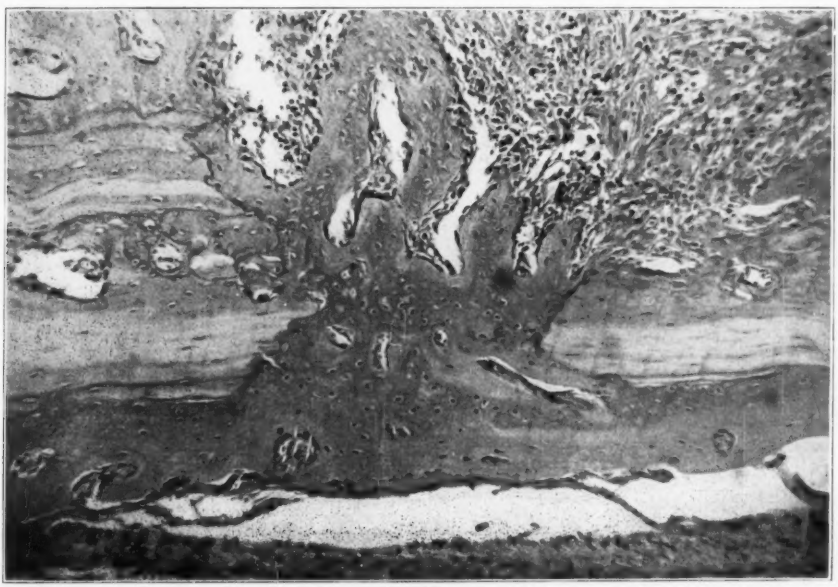


FIG. 10-B

Lateral cut (× 150). Showing union of lateral margin.

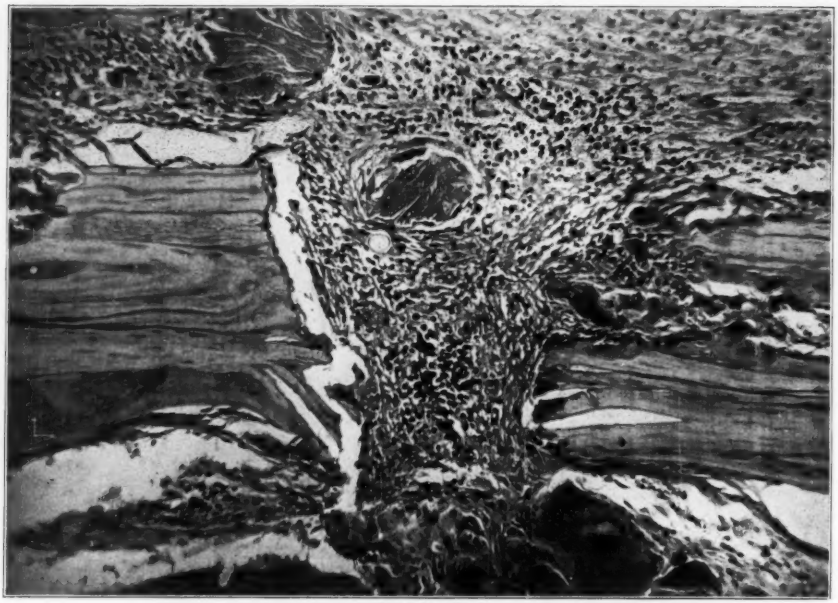


FIG. 10-C

Medial cut (× 150). There is fibrosis and no union of medial fracture margin.

Of eighteen animals employed in this experiment, the results in all those sacrificed on the sixteenth day or later are reported. Those sacrificed previous to the sixteenth post-operative day showed little or no osteogenetic activity.

Area 12, Sixteen Days: There was medial compression of the flap, but no contact-compression factor was applied to this portion. A bone flap was prepared according to the

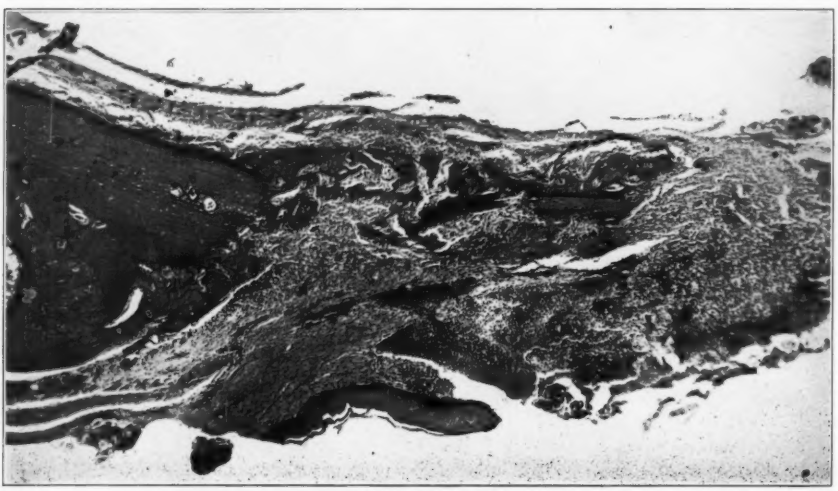


FIG. 11-A

Area 8, seventeen days (× 40). Lateral contact-compression factor was applied. Infection occurred; note necrosis and inflammatory cells. New-bone formation has occurred on lateral margin.

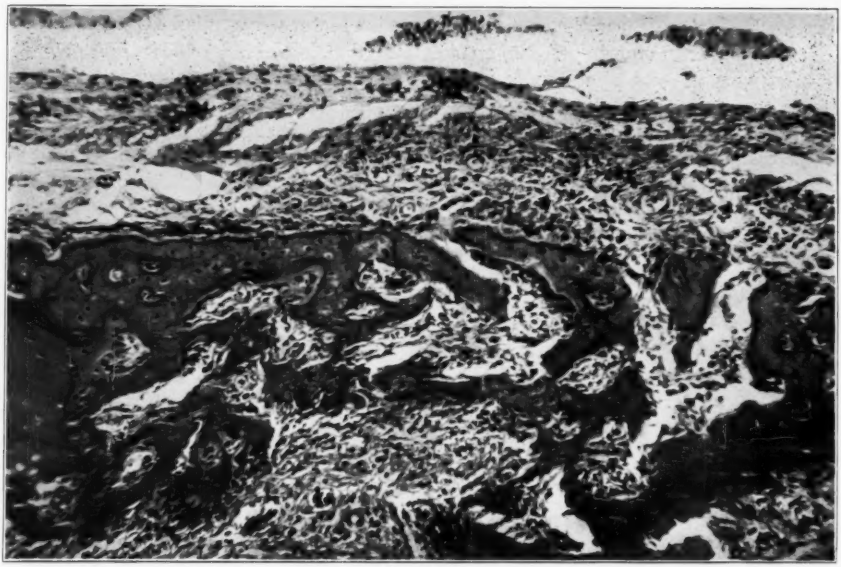


FIG. 11-B

Lateral cut (× 150). There is osseous activity on side of contact-compression factor in infected area. Saw-cut margin is seen on left.

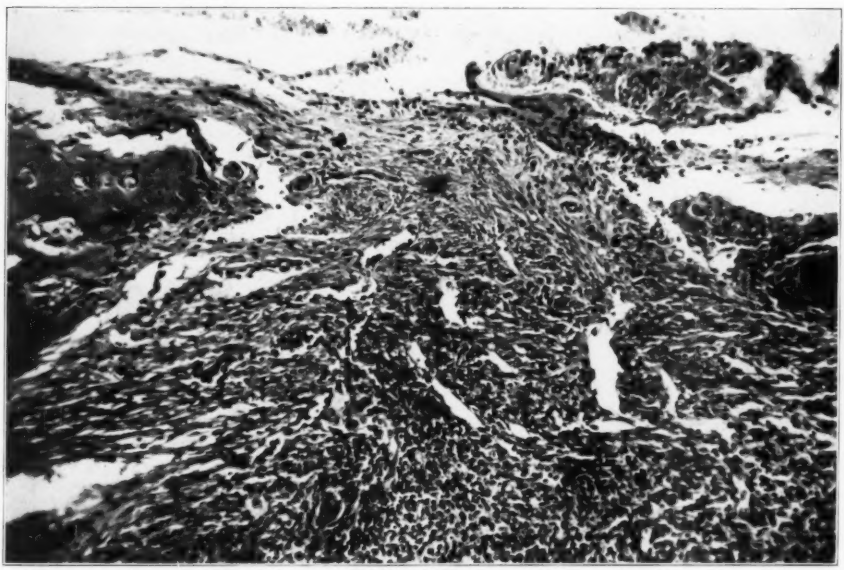


FIG. 11-C

Medial cut (× 150). Showing necrosis of bone and inflammatory cells on medial side. There is no attempt at union.

routine technique, but no pressure was applied to the control flap margins (Area 12). These remain relatively passive with no invasion of the fracture interval, although there is some surface activity (Figs. 7-A, 7-B, and 7-C). This is the control area of the experimental animal shown in Figures 8-A, 8-B, and 8-C.

Area 11, Sixteen Days: The contact-compression factor was applied to the medial side. The lateral (control) margin presents no effort at union. The medial side shows the formation of new bone, with simultaneous resorption of devitalized bone along the fracture margins and the typical reticulo-collagenous matrix (Figs. 8-A, 8-B, and 8-C).

Area 7, Sixteen Days: The medial contact-compression factor was applied. This section was made through the edge of the drill hole in which the small metal hook was placed. Under excessive pressure, this lateral area of the flap shows some necrosis and little osteogenesis. The medial fracture margins show marked osseous activity, both sides having received the benefit of the contact-compression factor (Figs. 9-A, 9-B, and 9-C).

Area 6, Seventeen Days: The lateral contact-compression factor was applied. The

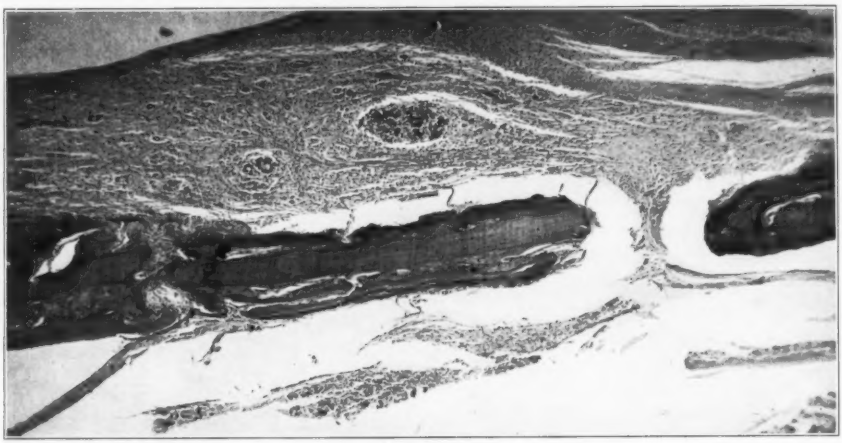


FIG. 12-A

Area 8, twenty days (× 40). Lateral contact-compression factor was applied.

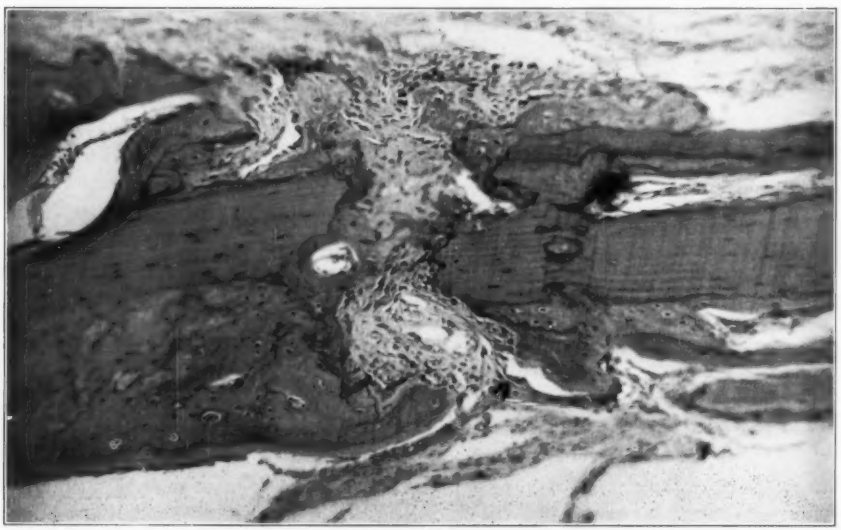


FIG. 12-B

Lateral cut (× 150). Showing osteogenesis and union.

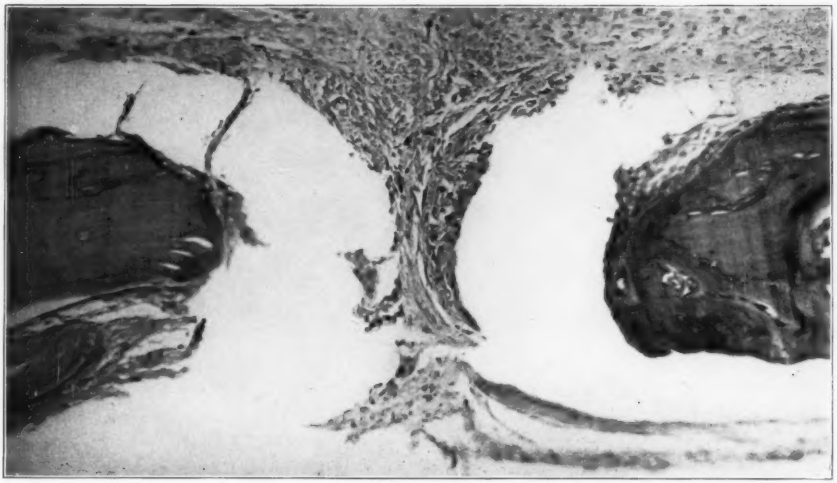


FIG. 12-C

Medial cut (× 150). There is no effort at marginal union.

fracture lines are well defined, and there is marked new-bone invasion with activity in the diploe and union on the lateral margin. There is no effort at repair of the fracture gap on the medial side (Figs. 10-A, 10-B, and 10-C).

Area 8, Seventeen Days: Lateral application of the contact-compression factor has been made (Fig. 11-A). This section was included because the animal was grossly infected. The marked destruction of bone and the associated bone activity are clear. Again, the important fact is that, in the presence of infection, osteogenetic activity is greater on the side (lateral) receiving the contact-compression factor. The medial side shows only marked bone necrosis and resorption (Figs. 11-B and 11-C).

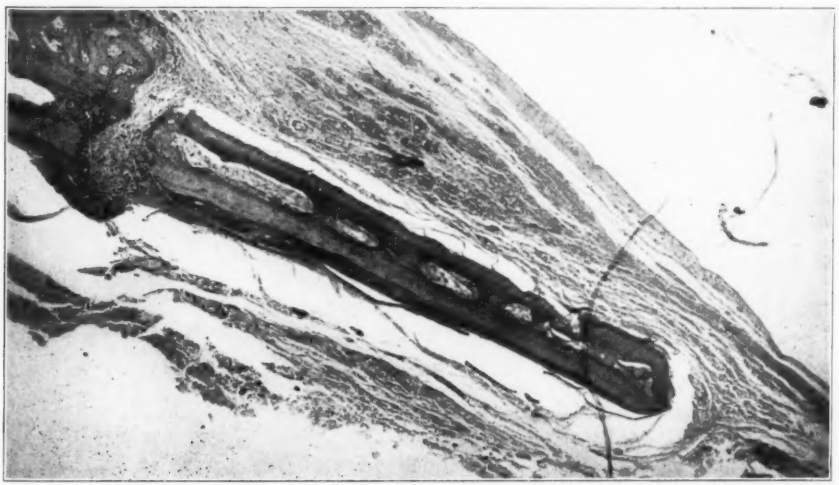


FIG. 13-A

Area 9, twenty days (× 40). Lateral contact-compression factor was applied. Union is active on lateral margin; fibrosis is present in medial gap.

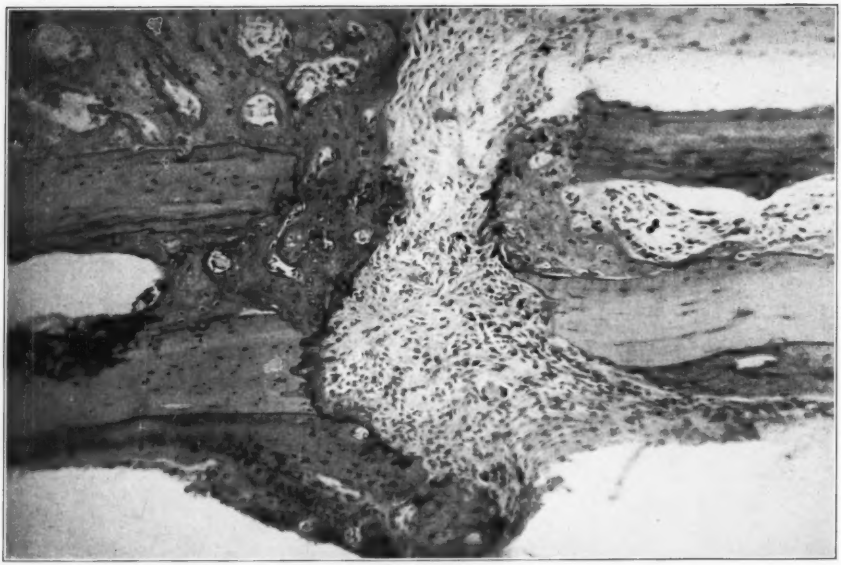


FIG. 13-B

Lateral cut (× 150). The osteogenetic activity on the compression side is impressive.

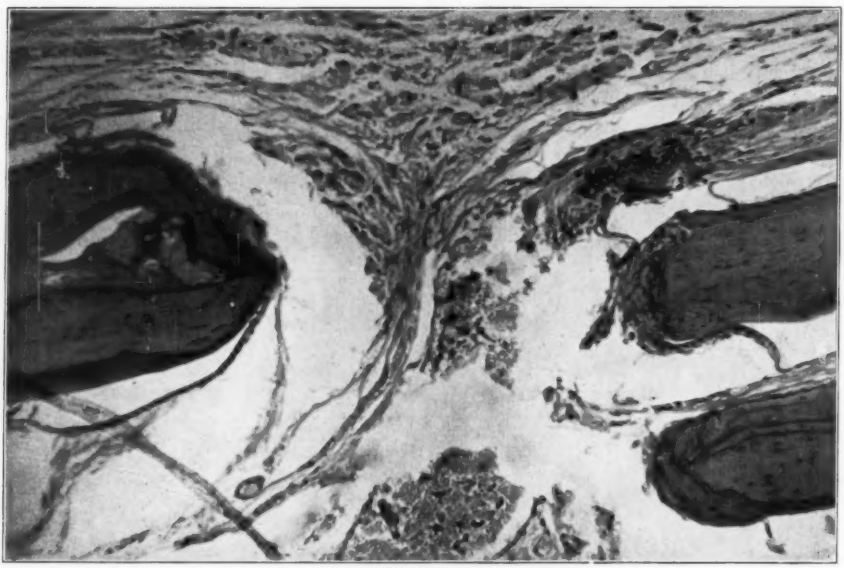


FIG. 13-C

Medial cut (× 150). Compare with Fig. 13-B.

Area 8, Twenty Days: The lateral contact-compression factor was applied (Fig. 12-A). The medial side shows no union, although the separation of the fracture margins is accentuated by retraction during fixation. The lateral margin is uniting, and the osteogenetic activity is well shown (Figs. 12-B and 12-C).

Area 9, Twenty Days: The lateral contact-compression factor was applied (Fig. 13-A). The osseous activity is evident on the lateral aspect, but is lacking on the medial (control) side. New bone is noted between the diploe, and early osteogenesis is seen between the fracture ends on the lateral border under the high-power magnification (Figs. 13-B and 13-C).

Area 8, Twenty-eight Days: The medial contact-compression factor was applied. The basic findings are repeated. Here the response is less complete, but the principle of reaction to pressure is constant (Fig. 14-A). This section is interesting because of the osseous

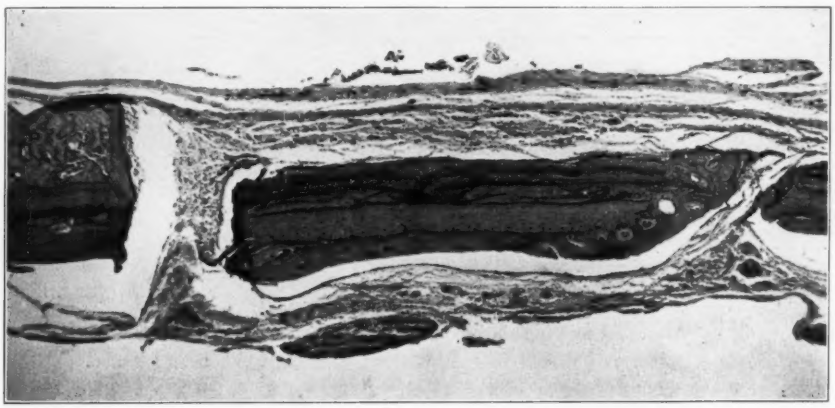


FIG. 14-A

Area 8, twenty-eight days (× 40). There was medial compression; saw cut was oblique on medial side. Some pressor effect was probably lost, which may explain why union is not complete on medial side.

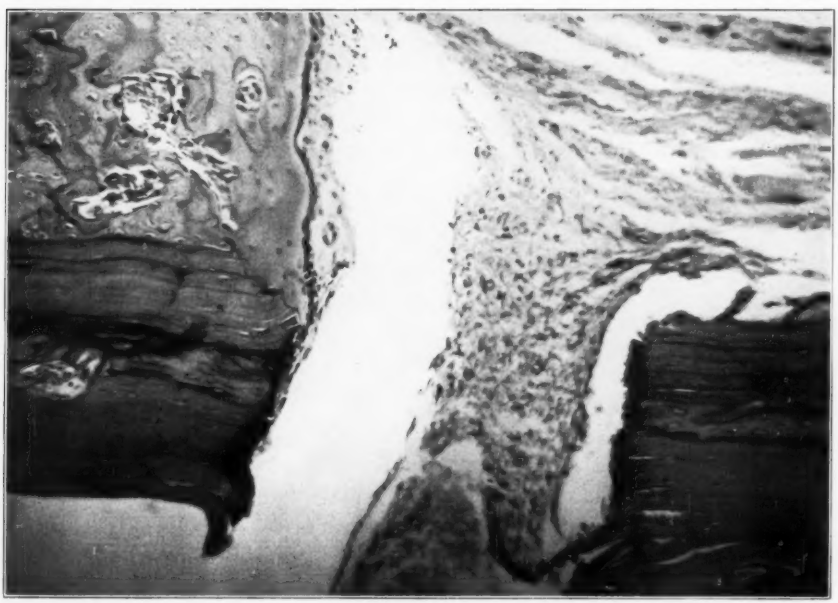


FIG. 14-B

Lateral cut (× 150). There is no union of lateral fracture margins.

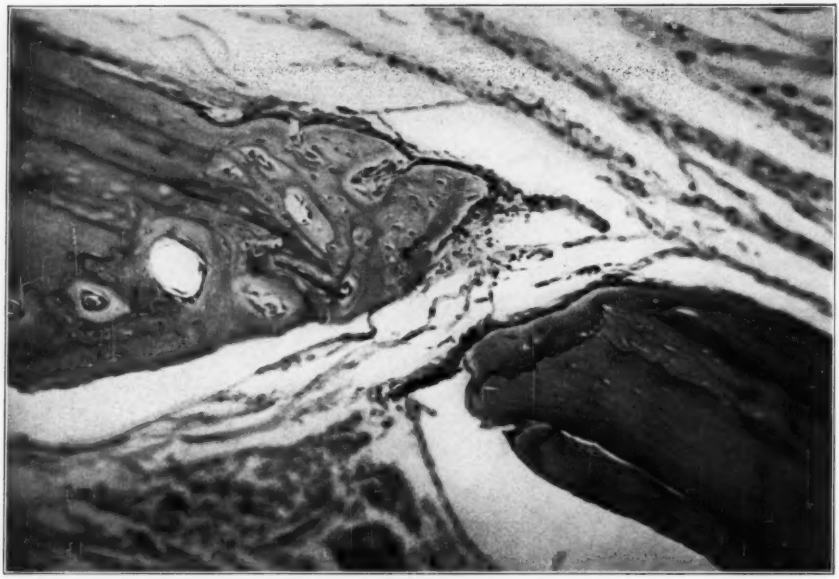


FIG. 14-C

Medial cut (× 150). Osteogenesis is active, especially on compressed margin. There is an effort at gap closure by medial margin of flap.

activity on the cutaneous side of the lateral skull margin, in contrast to the lateral aspect of the flap. Even though there was osseous activity (positional osteogenesis), the contact-compression factor was absent, and purposeful bony effort to bridge the lateral fracture gap is consequently lacking. The lateral flap margin is under no mechanical pressure and is totally inactive (Figs. 14-B and 14-C).

Area 9, Thirty-nine Days: The medial contact-compression factor has been applied. This section presents osseous activity on the medial side with union; the lateral border is ununited. Actual contact of the fracture margins is not present, but the margins are

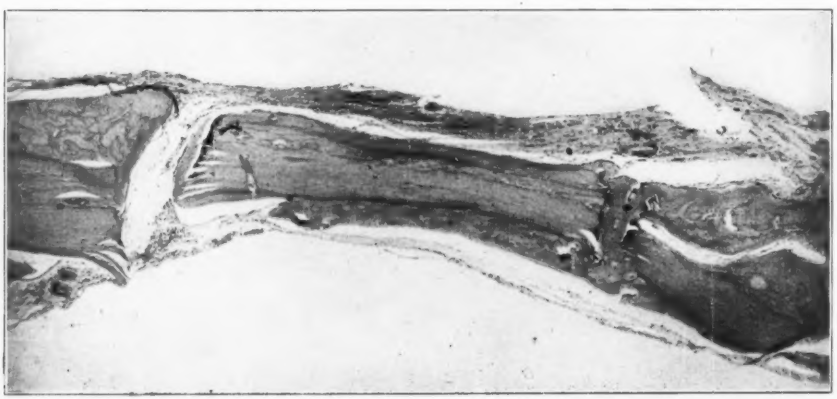


FIG. 15-A

Area 9, thirty-nine days (× 40). Medial contact-compression factor was applied. Osseous union has occurred on medial side; there is non-union of lateral margin.

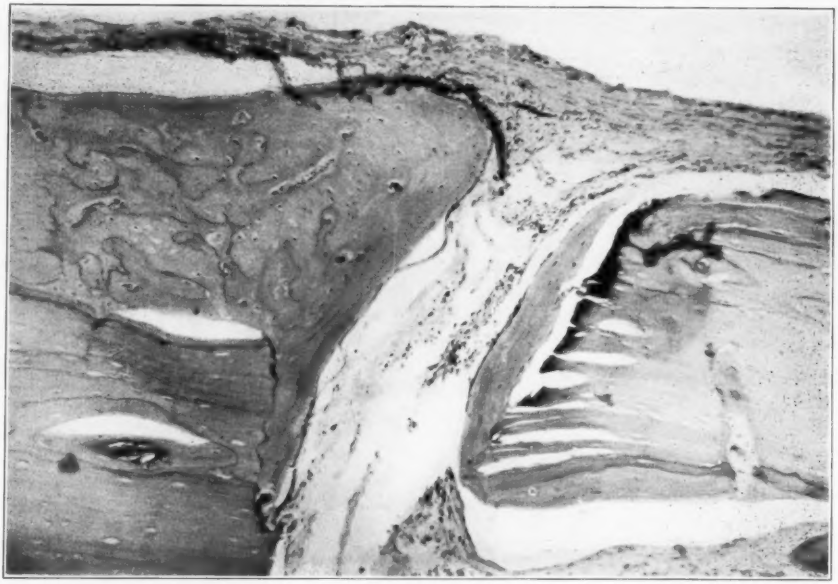


FIG. 15-B

Lateral cut (× 150). There is non-union. Osteogenesis is present, with no purposeful effort to fill the fracture interval from the lateral skull margin.

FIG. 15-C

Medial cut (× 150). Showing osseous union of approximated margins.

approximated. However, the osteogenesis proceeds across the fracture gap on the side of compression, but not on the non-compressed margin (Figs. 15-A, 15-B, and 15-C). This is significant.

Area 10, Forty-six Days: No contact-compression factor was applied. The contrast

with preceding illustrations is impressive. The lateral fracture line presents an absence of osteoblastic activity, and the medial side shows only fibrotic organization (Figs. 16-A, 16-B, and 16-C).

Area 9, Ninety-four Days: No contact-compression factor was applied. Both margins of the flap are ununited. There is some osseous activity, but no union of either fracture

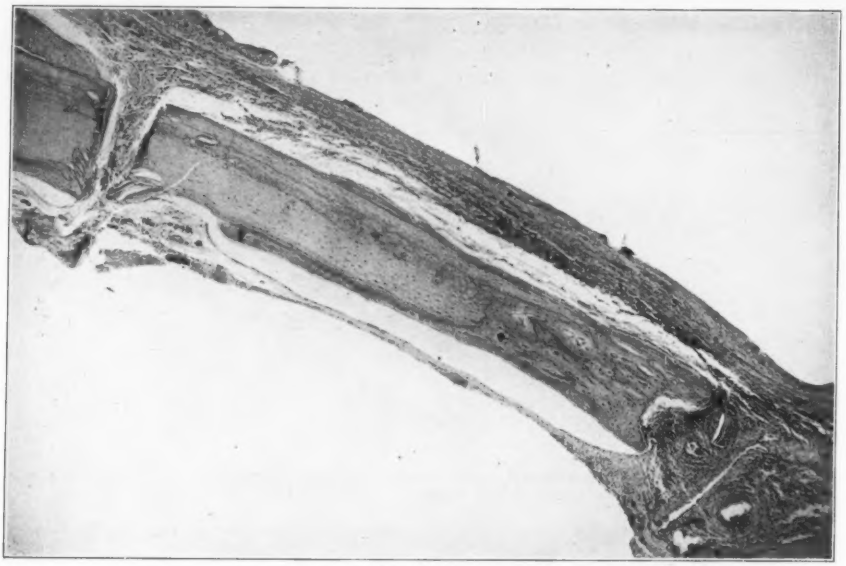


FIG. 16-A

Area 10, forty-six days (× 40). No contact-compression factor was applied.

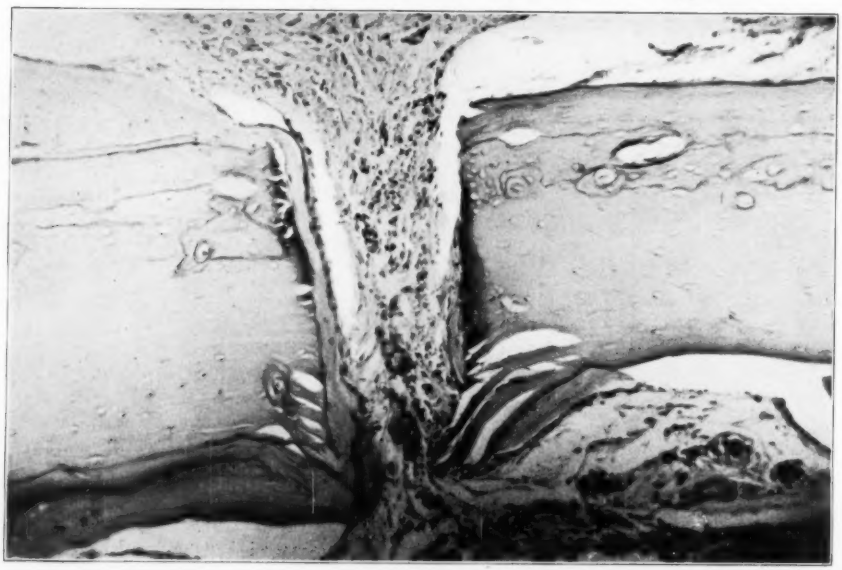


FIG. 16-B

Lateral cut (× 150). There is absence of osteoblastic activity.

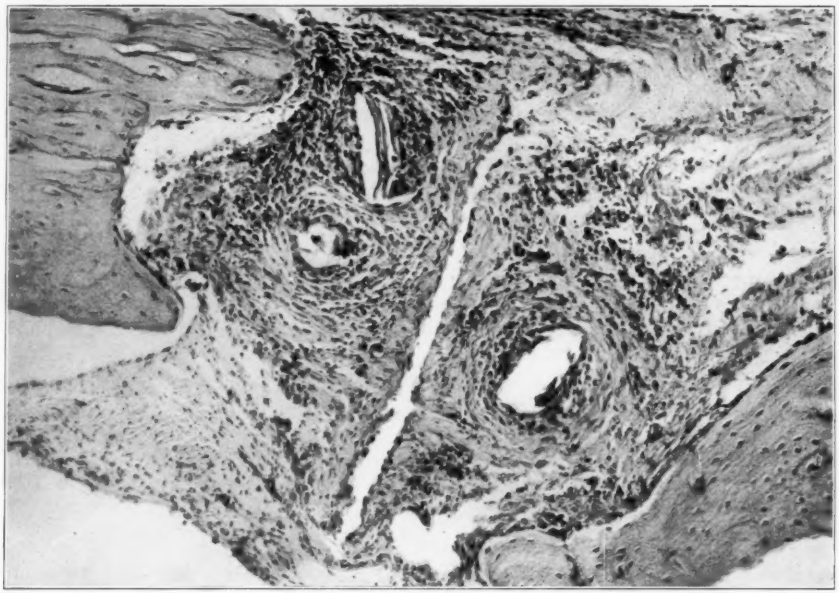


FIG. 16-C

Medial cut (× 150). Medial side shows only fibrotic organization.

margin (Figs. 17-A, 17-B, and 17-C). The significance of this ninety-four-day section with non-union is impressive, and becomes more so when contrasted with the seventeen-day sections on the side of the flap to which the contact-compression factor was applied and with the osteogenesis and union that followed.

COMMENT

The consistency of the findings throughout the experiments convinced the authors that the contact-compression factor was the only reasonable variable in the investigation. Union could be secured on either the medial or lateral aspect of the bone flap by choosing merely the side to unite and then applying the contact-compression factor to that side. If no union was desired, the flap was cut, and the contact-compression factor was not applied. Certainly, it seems reasonable to conclude that the contact-compression factor is important in stimulating osteogenesis and securing osseous union of fracture surfaces. The consistency and persistence of the same findings become impressive as one examines section after section, hundreds or more, and the findings are found to have been repeated in the same orderly fashion. This response of bone to the contact-compression factor can be utilized to clinical advantage.

The margins which received excessive pressure and contact became necrosed with a delay in osteogenesis; the margins under a more ideal pressure and contact had excellent osteogenetic activity; and the approximated margins with pressure applied made a determined osseous effort to bridge the intervening fracture gap. The serial sections clearly show the reaction to the varying pressure. Thus, the contact-compression factor with too much force caused necrosis; when absent, there was no osteogenetic response. These findings have convinced the authors that the optimal pressure is somewhere within the physiological limits of the force exerted by the musculature of the individual concerned.

SUMMARY

Experimentally, the authors produced union and purposeful osteogenesis in surgical

fractures in the area selected by applying the contact-compression factor alone. The microscopic sections are the factual evidence of this accomplishment.

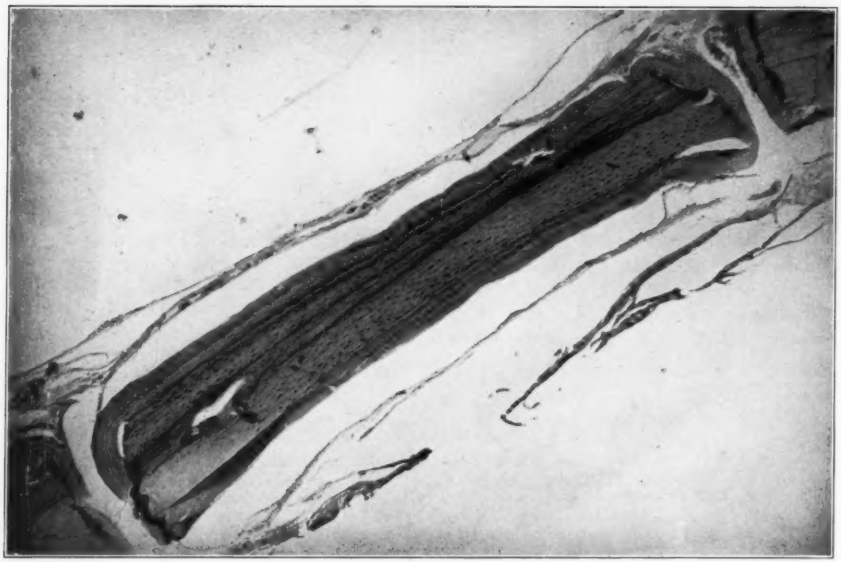


FIG. 17-A

Area 9, ninety-four days (× 40). No contact-compression factor was applied. There is non-union of medial and lateral margins.

FIG. 17-B

Lateral cut (× 150). Lateral fracture margins are not united.

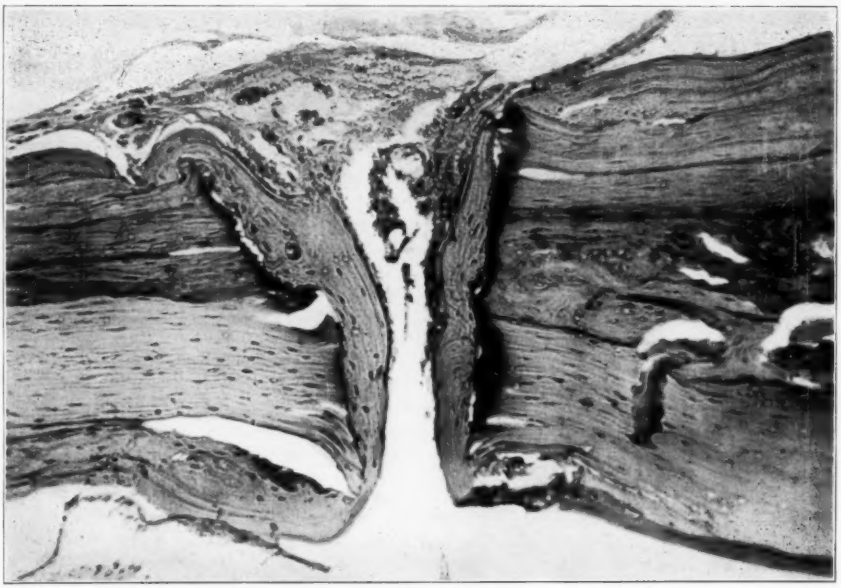


FIG. 17-C

Medial cut (× 150). Medial fracture margins are not united.

CONCLUSIONS

1. The contact-compression factor should incorporate compression forces in physiological muscle balance.

2. The presence of the contact-compression factor favorably influences purposeful osteogenesis and fracture union. Its absence fails to stimulate, but does not prevent, osteogenesis.

3. The presence of infection in the fracture site does not alter the tendency for osteogenesis to be more active in the area upon which the contact-compression factor is exerted.

4. Excessive pressure causes necrosis of the compressed bone, and lack of pressure fails to stimulate osteogenesis. The most advantageous compression force on the fracture surfaces apparently is mid-way between the extremes, and probably is exerted by the physiological forces of the musculature of the parts involved, to which the osseous structures are adjusted.

NOTE: The authors wish to express their appreciation to the United States Army Medical Library; United States Naval Research Grant (N_6-onr-266); Medical Library, Department of Medical Illustration, and Miss Estelle Greenwalt, University of Texas School of Medicine.

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DISCUSSION

DR. HUGH SMITH, MEMPHIS, TENNESSEE: Dr. Eggers' thought-provoking paper is representative of the type of work in which orthopaedic surgeons must engage in the future,—namely, physiological and pathological investigation of the fundamental processes of orthopaedic phenomena. The possibilities in clinical research, new surgical techniques, or mechanical appliances have not been exhausted, but the field is progressively narrowing. Rather than embark upon clinical studies alone, we must now turn to more basic research for original ideas.

From a purely clinical standpoint—and I have only clinical experience upon which to base my discussion—I believe that Dr. Eggers' thesis is correct: that contact-compression is one of the major mechanical factors in bone healing, and that clinical data substantiate his observations.

To a person believing in the necessity for absolutely rigid fixation of fractures, the success of the hanging-cast method of treating fractures of the humerus was somewhat disconcerting, and required a complete about-face in some of the fundamental beliefs in regard to bone healing. It would seem that, provided sheering forces are eliminated, a slight amount of motion or laxity of healing bone surfaces is desirable. However, both excessive motion and absolute rigidity should apparently be avoided.

Dr. Eggers' conclusions are most interesting and stimulating, and represent, I believe, a step in the right direction. My ideas of bone healing must again be altered. We have all been aware that diastasis adversely affects healing, and that apposition and contact are desirable. Other than as a means of maintaining contact, the effects of compression on osteogenesis have not been fully appreciated or generally accepted. As Dr. Eggers so aptly puts it, "this factor has been unwittingly utilized, purposely violated, or surgically created". I think it is natural that we should not accept this, or perhaps have a little reticence in accepting this contact-compression factor, since we are well aware that excessive compression is responsible for necrosis or osteoclasis. Dr. Eggers' findings show that there is much to be learned in regard to optimal mechanical conditions for the healing of bones. Certainly, there must be a common meeting ground for the various concepts of immobilization, positive pressure, or contact-compression.

If the optimum amount of pressure can be determined and controlled, the more widespread adoption of intramedullary pins, particularly for the femur, slotted plates, or various other mechanical appliances which take advantage of this contact-compression factor would seem logical.

DR. EDWARD L. COMPERE, CHICAGO, ILLINOIS: This paper by Dr. Eggers is both interesting and instructive. The method of this controlled investigation is exceedingly ingenious and the results appear to be incontrovertibly accurate.

Although this work has been done on bones which are preformed as membrane, while most fractures which the orthopaedic surgeon treats are in bones which are preformed in cartilage, Eggers states (and the experimental evidence seems to support his thesis) that the healing of fractures is identical in both membranous bone and in bone which has its origin in cartilage. The experiments described here confirm the opinions expressed by Charnley in 1948 and by Eggers in the same year, in an article dealing with clinical cases,—namely, that moderate compression aids the healing of fractures and hastens the processes of bone repair and osseous union in arthrodesis operations.

It is important that the clinician keep in mind the lessons which have been retaught by Dr. Eggers,—that compression without bone contact, such as that created by metal against bone, causes absorption. Marked compression-contact between two bones or between fragments of the same bone will produce necrosis. The well-established principle is still ignored by men lacking adequate training or the understanding of orthopaedic principles,—that distraction, even though contact may be retained, will delay the healing of fractures; and that distraction with loss of contact may lead to non-union.

In 1938, I carried out some experiments at the University of Chicago, in which I removed bone from the fibulae of dogs, trephined the calvarium in the same area as did Dr. Eggers, and switched the two bones, putting the fragment of fibula into the calvarium defect and bone of the calvarium into the defect created in the fibula. The skull bone united to the fibula, while the bone from the fibula, which had no pressure factor holding it into position in the calvarium, was slow to form even fibrous union.

The obvious conclusion from these experimental studies of Dr. Eggers, supported as they are by clinical experience, would be that minimal compression-contact creates the ideal situation for the most rapid healing of fractures or the obtaining of fusion following arthrodesis operations. The ideal compression forces are those created by the muscles themselves, as they envelop the bones of the extremities.

THE TRUMBLE OPERATION FOR FUSION OF THE HIP *

BY GEORGE W. VAN GORDER, M.D., BOSTON, MASSACHUSETTS

From the Lakeville State Sanatorium, Middleboro, Massachusetts

Numerous methods of performing extra-articular fusion of the hip joint are recorded in the literature, and among these is one which the writer believes should be more widely recognized. It is an ischiofemoral type of arthrodesis, advocated in 1932 by Hugh C. Trumble of Melbourne, Australia. This operation is especially suitable in cases of tuberculosis of the hip, where the disease is located in the superior portion of the acetabulum and the ilium, as well as in the joint proper, and where an iliofemoral arthrodesis would not only have little chance of success, but might produce irreparable harm.

Historically, it is of interest that, in 1931, Galland quoted Calvé as predicting that the time would come when the tuberculous hip joint would be fused successfully by the construction of a buttress on the adductor side of the joint. Curiously enough, one year later, this is exactly what Trumble succeeded in accomplishing when he devised his ischiofemoral fusion operation. The principle of the operation is to establish a bridge of bone between the ischium and the femur, just below the hip joint, in an operative field which is supposedly free from tuberculous contamination (Fig. 1). With fusion of this bony bridge, which is promoted by the action of the adductor muscles of the thigh, strain is taken away from the diseased joint and healing of the tuberculous process is encouraged.

A description of the operation follows:

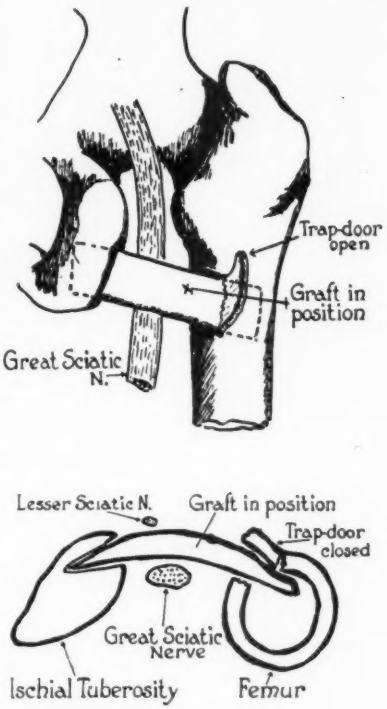

FIG. 1

Schematic representation of the original Trumble operation. (Reproduced, by permission, from article by H. C. Trumble in *Australian and New Zealand Journal of Surgery*, 1: 417, 1932.)

PREOPERATIVE PREPARATION

Several days before the operation, the patient has a one and one-half spica cast applied, with the diseased hip held in the proper position for fusion and a dummy dressing placed over the operative field. The cast is bivalved the following day, in such a way as to permit adequate exposure of the operative field when the posterior half is removed (Fig. 2). Because the anterior half must necessarily be narrowed considerably in the region of the groin, a steel bar should be incorporated in this portion of the cast for strength. Both halves are lined with stockinette and allowed to dry thoroughly.

The day before the operation, the affected limb is prepared for surgery. The previously constructed bivalved plaster cast is applied over the sterile toweling and is worn, in order to be sure that the cast is comfortable.

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 18, 1949.

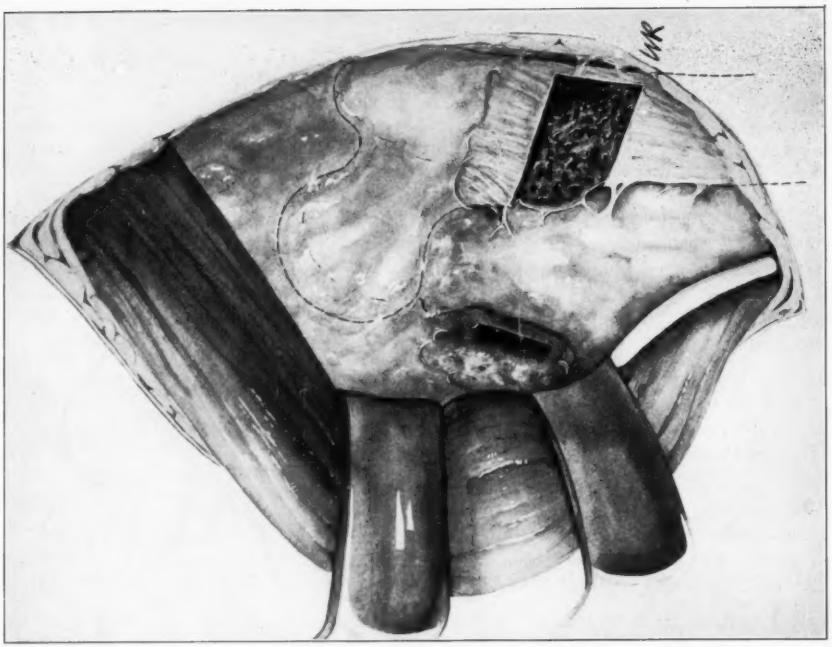

FIG. 3-A

FIG. 2

Fig. 2: Position of patient on the operating table, lying in the anterior portion of a bivalved plaster cast. The operative incision is shown.
Fig. 3-A: Preparation for graft.

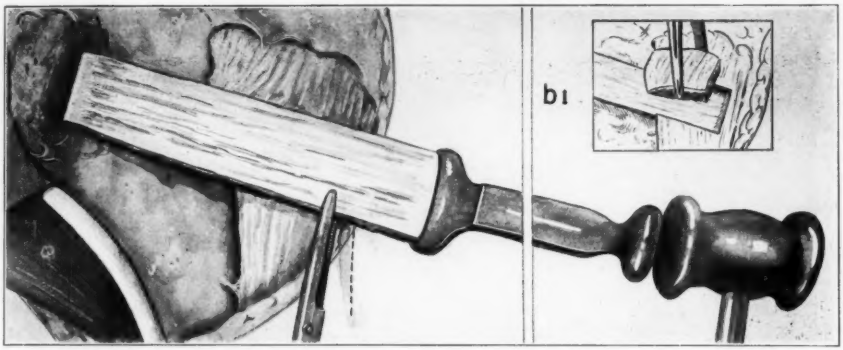

FIG. 3-B

Insertion of graft into ischium. Inset shows graft countersunk into femoral mortise; bone block is being replaced.

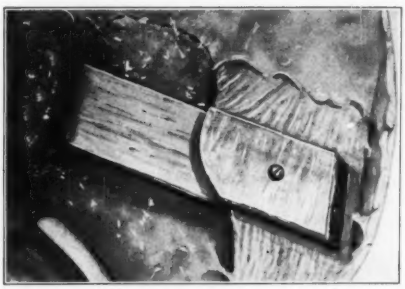

FIG. 3-C

Graft has been secured in position.

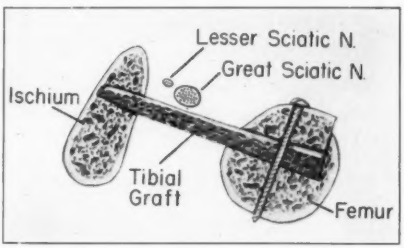

FIG. 3-D

Cross section shows fixation of graft.

THE OPERATION

With the patient lying face down in the anterior half of the plaster shell on the operating table, an incision is started at the tip of the greater trochanter and is carried downward and medially to a point one inch below the gluteal fold in the mid-line (Fig. 2). The incision is deepened through the fascia lata to expose the trochanteric bursa in the upper portion of the wound and, a little below this, the osseous insertion of the glutaeus maximus. The latter structure is most easily identified by placing the finger under the fascial insertion of the glutaeus maximus in the upper portion of the wound and dissecting distally for a short distance; the osseous insertion can be felt readily, attached to the posterior surface of the femur. Once this has been located, it is completely isolated by passing any long curved instrument behind it. The osseous insertion is then divided, about one-half inch from the bone, to allow for future suturing; the division is best made between clamps so as to control bleeding.

When the muscle insertion has been divided, it is quite easy to elevate the remaining portion of the glutaeus maximus from the underlying soft parts by simply deepening the lower limb of the incision. Caution should be observed in doing this, however, because the posterior femoral cutaneous nerve (lesser sciatic nerve) lies rather superficially, as it emerges from beneath the glutaeus maximus in the mid-line, and careless or deep dissection at the extreme lower end of the wound might injure it.

The whole flap, consisting of skin, subcutaneous tissue, deep fascia, and glutaeus maximus, is rolled upward and medially, bringing into view the sciatic nerve. The nerve should be clearly identified before proceeding further, but it should not be dissected from

FIG. 4

Case 1 (A.G.), four and one-half years after Trumble operation. Note the marked hypertrophy of the tibial graft. Patient is well and free from symptoms; the sinus has remained healed. The right sacro-iliac joint had been fused for tuberculosis, one year prior to the hip fusion.

its surrounding soft parts, or handled in any way other than to be gently and carefully retracted along with the glutaeus maximus. No attempt is made to separate the posterior femoral cutaneous nerve from the sciatic nerve, and both are carried on the deep surface of the glutaeus maximus while it is being drawn toward the mid-line during the remainder of the operation.

The operator then palpates the tuberosity of the ischium and divides the fascial and periosteal layers overlying it, to expose the bone subperiosteally. After this has been done, a measurement is taken with a ruler or caliper to determine the required length of the tibial graft, as follows: The distance between the ischium and the lateral edge of the femur at the desired angle is noted, and to this measurement is added an inch and a half, which will represent the amount of penetration of the graft into the ischium. After the proper length has been obtained, the hip wound is covered with a sterile towel and the tibia is exposed.

By flexing the knee of the limb which is being operated upon, the anterior surface of the tibia is brought into view, and from this area a full-thickness cortical graft is removed with an electric saw. This graft should be the width of the entire anteromedial surface of the upper end of the tibia. Its length, as just mentioned, should be one and one-half inches longer than the measured distance between the ischial tuberosity and the lateral edge of the femur; and its thickness should comprise endosteal bone from the marrow cavity, as well as the heavy cortical bone layer with its periosteum. The narrow end of the graft is sharpened after removal, so that it may be driven more readily into the substance of the ischium.

The leg wound is closed by an assistant, while the operator arranges for placement of the graft. A window or slot is cut in the exposed cortex of the ischium; as this is done, the blade of the osteotome should be flat against the shaft of the femur, so as to ensure that the graft will lie in the proper plane and fit accurately when driven into the substance of

the ischium. The size of the ischial window (usually one inch by one-quarter of an inch) should correspond to the width and thickness of the tibial graft. After the window has been cut, an osteotome is driven through the opening to the opposite cortex and levered up and down several times to facilitate penetration of the graft. The sharpened end of the graft must fit snugly into the window of the ischium and, at the same time, its rough, cancellous surface must lie flat against the posterior surface of the femur, at the desired angle. The graft thus being used as a marker, a block of bone is cut from the posteromedial portion of the femur, after the overlying soft parts have been excised or retracted out of the way. The depth or thickness of this block of bone is about one-half the diameter of the femur, and care is taken not to have it include the lateral femoral cortex, which should remain intact. The block is outlined with a sharp osteotome and removed as one solid piece of bone, to be saved for future use.

The ischium and the femur have thus been prepared for the introduction of the tibial graft (Fig. 3-A). A slot has been cut in the ischium to receive the sharpened end of the graft, and a mortise has been prepared in the femur, into which the blunt end of the graft is to fit. It remains only to drive the graft into the substance of the ischium to a point which will allow its broad, blunt end to fit into the femoral mortise (Fig. 3-B). After this has been accomplished, the lateral end of the graft is countersunk into the mid-portion of the femur; the block of bone previously removed is placed on top of it (Fig. 3-B, inset) and held securely by a stainless-steel screw, which penetrates the bone block, graft, and deep femoral cortex, locking them together (Figs. 3-C and 3-D).

After the graft has been securely embedded, the retracted gluteal-muscle flap is released and the soft parts automatically fall back into anatomical position, with the

FIG. 5

Case 2 (M.L.), three years after Trumble operation. The first operation to fuse the right hip by an iliofemoral arthrodesis, in January 1946, was discontinued because of an acute tuberculous process with abscess in the superior acetabular region of the ilium. Five months later, a Trumble ischiofemoral fusion was performed. At the present time, the patient is in excellent health, is symptom-free, and her hip sinus has remained closed for three years. Note that the graft has become firmly integrated into the bony structure of the hip. The patient's lumbar spine had been fused five years prior to hip fusion.

FIG. 6

Case 3 (C.D.), two years and ten months after Trumble operation. The tibial graft has become hypertrophied, and there is solid bony union of graft and hip joint. Two sinuses have remained healed since four months before operation. The patient is active and well.

FIG. 7

Case 4 (A.D.), two years and seven months after Trumble operation. Note that there is firm bony union between femur and ischium. The patient is active and well, and all of his sinuses are closed.

FIG. 8

Case 5 (W.F.), two years and six months after Trumble operation. An error in diagnosis was made in 1942, when a cup arthroplasty was performed. The operation was unsuccessful and the cup was removed. A diagnosis of tuberculosis was established, and iliofemoral fusion was attempted in 1943. The fusion was not successful. A second attempt at iliofemoral fusion was made in 1944; this also failed and three sinuses developed. The patient was then sent to Lakeville State Sanatorium, where a Trumble ischiofemoral arthrodesis was performed in November 1946. Note that graft has become hypertrophied and that the hip joint has fused. During her convalescence, a tuberculous lesion was discovered in the patient's spine and a spine fusion was carried out successfully. At present, she is active and well and her three tuberculous sinuses have remained healed.

sciatic nerve and the posterior femoral cutaneous nerve lying superficial to the smooth cortical surface of the tibial graft. The previously divided glutaeus maximus insertion is next sutured, and the wound is closed in the usual way.

The posterior half of the plaster cast is then placed over the sterile dressings on both leg and hip and is attached securely to the anterior portion, in which the patient has been lying during the operation.

MODIFICATIONS OF THE TRUMBLE TECHNIQUE

The foregoing description of the operation differs in a few minor respects from that originally given by Trumble. For instance, he uses a posterior plaster shell for external fixation instead of a one and one-half spica cast. Also, he anchors the tibial graft into the femur by a trap-door method (Fig. 1), as contrasted with the metallic screw fixation which the author prefers, because it is much simpler and more secure (Figs. 3-C and 3-D). Trumble also separated the posterior femoral cutaneous nerve from the sciatic nerve and placed them on opposite sides of a curved tibial graft. This procedure has not been tried in the present series of cases; these nerves were carefully left undisturbed, except for gentle retraction under the glutaeus maximus. Moreover, the tibial graft was a straight one, instead of curved.

Finally, the sound limb, as a rule, was selected by Trumble to supply his tibial graft, whereas the writer has felt that it is unwise to involve the sound leg, unless absolutely necessary. Sometimes, because of a marked decrease in size of the affected limb or the presence of local disease, the sound side will provide a healthier and larger tibial graft. In such instances, of course, the good leg should be used.

TABLE I

SUMMARY OF DATA IN SEVEN PATIENTS

Case No.	Patient	Age and Sex	Duration of Disease	Associated Lesions	Recumbency after Operation (*Months*)	Follow-up Duration	Follow-up Results
1	A.G.	43 F.	2 yrs., 9 mos.	Tuberculosis of right sacro-iliac joint; sinus in right upper thigh	6	4 yrs., 6 mos.	Fusion
2	M.L.	38 F.	2 yrs., 6 mos.	Tuberculosis of spine; pulmonary tuberculosis; lateral hip sinus	6	3 yrs.	Fusion
3	C.D.	17 F.	3 yrs., 5 mos.	Two sinuses in groin	6	2 yrs., 10 mos.	Fusion
4	A.D.	15 M.	7 yrs., 5 mos.	Three sinuses,—lateral portion of hip, abdomen, and groin	6	2 yrs., 7 mos.	Fusion
5	W.F.	24 F.	5 yrs., 2 mos.	Tuberculosis of spine; three sinuses in lateral portion of hip	13	2 yrs., 6 mos.	Fusion
6	L.D.	32 M.	3 yrs., 4 mos.	Sacro-iliac and pulmonary tuberculosis; three sinuses in anterior, medial, and lateral portions of thigh	8	1 yr., 7 mos.	Fusion
7	E.N.	41 M.	1 yr., 7 mos.	Pulmonary calcaneal nodes; sinus in lateral portion of hip	6	1 yr.	Fusion

DISCUSSION

There are three or possibly four contra-indications to the Trumble operation, which are self-evident:

1. When marked deformity of the hip exists, resulting in a wide separation of the ischium and femur;

2. When active disease is present in the ischium or the subtrochanteric region;

3. When draining sinuses are present in the posterior portion of the hip and thus contaminate the operative field.

4. Another possible contra-indication may be when the head of the femur is dislocated or has no firm contact with the acetabulum or ilium.

It should be remembered that this operation is applicable only for hip joints that preoperatively are in a proper position for fusion and weight-bearing. It is in no sense a procedure to correct deformity, but is intended only to fuse and consolidate the bone structures in the position where they already are.

During the time that the author has been employing the Trumble operation for tuberculosis of the hip, many questions have arisen, such as:

1. Can the operation be done at an early stage of the disease while the condition is still acute, thus preventing the possibility of excursion of the femoral head or neck upward on the blade of the ilium?

2. Now that streptomycin is available, need one wait for subsidence of acute symptoms before carrying out this type of surgery?

3. For how long a period of time is external immobilization necessary following the Trumble operation? How much protection is actually required after operation? When should weight-bearing be started?

4. Does the diseased area of the hip joint, *per se*, heal or fuse after this operation? If so, how long does it usually take?

5. How important is the angle at which the graft is placed? Does this influence the time of healing of the tuberculous process? Does it affect the final result?

6. Is hypertrophy of the tibial graft mainly the result of adductor-muscle pull or of weight-bearing?

These and many other questions will be answered in the course of time, as our experience grows. At present, all the writer can say from personal knowledge is that, given a proper selection of cases in which the hip disease is quiescent, and a sufficient period of postoperative protection (an average of six months) in a plaster cast, the Trumble operation has proved more successful than any other form of extra-articular arthrodesis of which he knows.

As far as we can tell from the patients operated upon, not only does the graft remain alive and fuse, but the disease also tends to heal. Fusion of the joint itself evidently requires a much longer period of time, and will depend largely upon the extent and character of the disease process.

From our experience with this operation, it does not seem to be of vital importance whether the graft is placed at a right angle to the shaft of the femur or more in line with its weight-bearing force. No one rule has been followed in the placement of our grafts as far as angulation is concerned, and yet all have healed well and all have become hypertrophied. Theoretically, those grafts which are placed more in the line of weight-bearing should become hypertrophied to a greater degree, at least until healing of the disease takes place. Nevertheless, we find that graft hypertrophy takes place in some instances before any weight-bearing is started.

FIG. 9

Case 6 (L.D.), one year and seven months after Trumble operation. Note hypertrophy of the tibial graft. One year after operation, the patient fell downstairs and fractured the tibia and fibula of his affected leg, without disturbing the ischiofemoral graft. He is now active and well and all three sinuses have remained closed. His right sacro-iliac joint had been fused three years before the hip fusion.

FIG. 10

Case 7 (E.N.), one year after Trumble operation. Note presence of tuberculous disease in greater trochanter as well as in acetabulum. This was present before operation. The graft has become hypertrophied to a greater extent at the ischial end, but seems to be solid also at the femoral attachment. Clinically, fusion is solid and the hip is painless.

In all probability, this is due to adductor-muscle pull. Could it not be, then, that the tibial graft is influenced by both forces, and that early hypertrophy of the graft is due to adductor influence and late hypertrophy to weight-bearing?

If neither tibia is suitable for supplying a bone graft, either because of local disease or some other cause, it is quite easy to retract the thigh muscles of the operative hip wound and to take a graft from the femur, just distal to the prepared mortise. The author has done this successfully in a patient whose prepared tibia was underdeveloped and, therefore, not suitable as a donor site.

SUMMARY

Thirteen patients with tuberculosis of the hip joint have been treated at the Lakeville State Sanatorium, by the Trumble operation. Of these, seven had their operations more than one year ago and have solid bony fusion (Table I). The remainder have not been treated sufficiently long for a final end result. All of the patients are doing well, however, and the outlook for successful fusion is excellent. So far, there have been no failures and only two complications.

One complication concerned a tibial graft which slipped out of the window in the ischium, because the graft had been cut too short. This was a technical error in measurement, and the graft did not penetrate into the substance of the ischium. A graft of greater length, taken two weeks after operation from the opposite tibia, was used to replace the dislocated one. Instead of discarding the short graft, it was put into the bed of the tibia from which the longer graft had just been removed. Healing progressed favorably after the second operation.

The second complication had to do with a small pressure area over the head of the fibula, produced by the plaster leg cast, which caused a transient peroneal palsy. A window was cut in the cast to relieve this pressure, and the signs of paralysis soon began to disappear. Full recovery resulted.

Roentgenograms of the seven patients whose operations were performed a year or more ago are shown (Figs. 4 to 10, inclusive).

CONCLUSION

While the small number of cases reported in this paper do not warrant any infallible conclusions, and the report should be considered preliminary, yet the writer is convinced that the Trumble type of ischiofemoral arthrodesis is the best form of extra-articular fusion for the hip joint that has yet been devised. In his opinion, it should be used more extensively.

NOTE: Since the presentation of this paper, three additional cases have been followed up at a period of one year after operation. All show solid, bony fusion, making a total of ten successful cases to date.

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A TECHNIQUE FOR ARTHRODESIS OF THE HIP JOINT*

BY ALAN DEFOREST SMITH, M.D., AND ORREN D. BAAB, M.D., NEW YORK, N. Y.

From the Clinic of the New York Orthopaedic Hospital

Arthrodesis frequently is difficult to accomplish in osteo-arthritic hips. The bone is sclerotic and relatively avascular, and the capsule and synovial membrane usually are thickened and fibrotic. The patients often are obese, and effective immobilization in a plaster spica is difficult or impossible. Therefore, internal fixation by some form of metal has been found advantageous in these operations. A method of driving multiple square nails from the ilium into the femoral head and neck has been evolved; this method has been successful in a small series of cases, and it is believed that it offers certain advantages in some of these operations.

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 18, 1949.

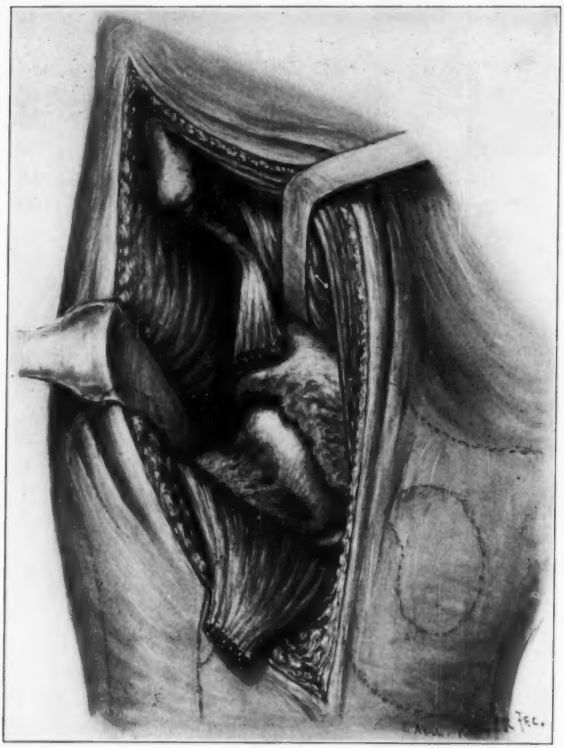

FIG. 1

Exposure of hip joint. The quadriceps is detached from the anterior inferior spine of the ilium, and not at the point indicated.

The method was first used in a modified form in 1943, in an operation on an obese woman, fifty-two years old, who was to have had fusion of the left hip because of painful osteo-arthritis. The joint was exposed by a Smith-Petersen incision and the intention was to use an iliac graft, after removal of the cartilage from the superior portion of the head and acetabulum. Before this could be done, however, the patient's condition became bad, and it was deemed wise to terminate the operation as soon as possible. A wide osteophytic lip protruded from the upper margin of the acetabulum, and Robert J. Neville, who was assisting, suggested that two square nails be driven through this, into the femoral head. This was quickly done and, after closure of the incision, the patient was returned to bed without any form of external fixation being applied. At the end of twelve weeks, the fusion appeared to be solid enough to permit her getting up. The fusion has remained firm and the pain in her hip has been relieved.

The success in this case suggested further use of the method. The technique has been modified, however. The capsule of the hip is exposed as widely as possible through a Smith-Petersen incision (Fig. 1), as for a cup arthroplasty. Care is taken to dissect the overlying gluteal and psoas muscles as widely as possible from the capsule; the superior and antero-inferior portions of the capsule are completely excised. This is considered an important step in the operation. Not only does it afford an excellent exposure of the joint, but it achieves direct contact of vascular muscles with the area in which bony union is sought, in place of the thick, fibrous, relatively avascular capsule.

The femoral head is then dislocated, and the remnants of articular cartilage are removed from the head and the acetabulum. No attempt is made, however, to remove all of the sclerotic bone. Good contact should be retained between the head and acetabulum; and, if much bone were removed, this would not be possible. Numerous holes are drilled in the head and surface of the acetabulum, in order to facilitate the growth of blood vessels into the area. The head is then replaced.

In exposing the joint, the rectus and psoas muscles are separated. The psoas and iliacus are carefully stripped from the inner surface of the ilium, the inner wall of the anterior portion of the acetabulum thus being easily exposed. The hip is placed in the

desired position,—usually about 25 degrees of flexion, neutral rotation, and little or no abduction. Two square Vitallium or stainless-steel nails with flat, rounded heads are driven from within the pelvis through the acetabulum, into the head and neck of the femur. One of the nails should be long enough (about three and one-half inches) to traverse the greater part of the neck. It is better to introduce the nails in slightly different directions, so that they are not parallel. If there is an osteophytic lip on the superior rim of the acetabulum, as often is the case (Fig. 2-A), a similar but shorter nail is driven downward through it, to transfix the head in a vertical direction. Thus three nails traverse the ilium and femur in different planes, so that fixation of the head is very firm (Figs. 2-B and 2-C).

Closure of the muscles over the ilium is greatly facilitated by removing a strip of bone, an inch or so in thickness, from the iliac crest. Some of this bone can be used to good advantage as packing around the margin of the acetabulum. No effort is made to place bone inside the acetabulum, because this would disturb the even contact which has been obtained between it and the head.

The wound is then closed in layers. A plaster spica may be applied or not, as seems fit. In several of the authors' cases it was omitted, and it is believed that it would be safe to do so in most instances. The period during which the patient is kept in bed has varied from two or three to twelve weeks. Early ambulation should be possible in an increasing number of cases.

The technique has been designed especially for osteo-arthritic hips. It has been used in other conditions, such as arthritis following congenital dislocation or subluxation, and suppurative arthritis. It is not recommended in cases of tuberculosis, or when there is likelihood of a pyogenic infection becoming reactivated. In some cases the technique has been modified by the use of two instead of three nails, and by introducing all of them into the pelvis from without. Although this has succeeded in a few cases, it is not considered as good as the method described here. The nails driven from within have a firm hold on the ilium, even though they penetrate its thinnest portion, which is not true of those which are driven in from without.

Up to November 30, 1948, fourteen patients, eight females and six males, were operated upon by the technique described. Their ages varied from ten to sixty-four years, the average age of the males being forty-nine, and that of the females thirty-six and one-half years. Fusion resulted in twelve cases. In two, solid union failed to develop after seven months, and the results must be classed as failures. One of these patients had had two previous attempts at arthrodesis by other methods; there was a large amount of scar tissue around the joint, and the bones were very sclerotic. In the other case, with aseptic necrosis of the femoral head following fracture, the mistake was made of removing too much bone from the femoral head and acetabulum, thereby diminishing the area of contact.

In five other cases two or more nails were used, but otherwise the technique varied considerably from that described, making these cases unsuitable for inclusion in the series. Solid fusion was achieved in four. In the one failure in this group, the cartilage was removed only from the upper portion of the head and acetabulum. A bone graft was placed along the upper surface of the neck and head, penetrating the acetabulum, but without fixation in the ilium. When a second operation was done on this patient, it was found that one of the intrapelvic nails had become loose and had protruded a slight distance into the pelvis. It was removed without undue difficulty.

In two patients in the series of fourteen, pulmonary infarction developed after operation, presumably from thrombophlebitis. Both patients recovered. Philip Wilson noted several cases of thrombophlebitis after hip-fusion operations in which a Smith-Petersen nail had been driven through the head and neck of the femur from inside the ilium, and suggested that the separation of the iliacus muscle from the inside of the pelvis

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Osteo-arthritis of the hip, with a projecting ledge of bone.
Figs. 2-B and 2-C: Anteroposterior and oblique views after insertion of nails, two from inside the ilium.

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Osteo-arthritis of hip joint, probably resulting from congenital subluxation.
Figs. 3-B and 3-C: Anteroposterior and oblique views with nails in place.

might predispose to this condition. In our experience, however, this has not happened after arthroplasties, in which the iliacus is similarly elevated from the pelvis.

DISCUSSION

DR. CARL E. BADGLEY, ANN ARBOR, MICHIGAN: It is a great privilege to have the opportunity to discuss these two excellent papers. We have here the problems Dr. Smith has brought up, of extra-articular fusion for osteo-arthritis and for tuberculosis, and of intra-articular fusion for osteo-arthritis.

I must confess a complete ignorance of the Trumble procedure. As far as I am concerned, this would be known as the Van Gorder operation. However, it is based on the principles that Brittain utilized. We are familiar with the results of the Brittain operation. Dr. Van Gorder's operative technique has been beautifully presented by the motion picture. Technically, it surpasses the Brittain procedure; and it is one that we will all readily adopt, whereas I have been hesitant to adopt the Brittain procedure, with its method of blind insertion of the graft. I think the visualization of the fragments, made possible, will be employed not only for the procedure that we have seen today, but for a number of other conditions. I have utilized a similar approach for subtrochanteric fractures, the glutaeus maximus attachment to the linea aspera being used as a guide to the displaced lower fragment of the femur, without any muscle being traversed or sectioned. I have been able to get complete reduction very readily in a badly displaced fracture.

I can see where Brittain's type of complete osteotomy may be utilized by Dr. Van Gorder in cases where there are deformities of the hip. In his paper he emphasized that the Trumble operation is not applicable in case of deformity. Only when there is proper position can you utilize his operation. However, I can conceive of doing a transverse osteotomy by his approach, correcting the deformity, and utilizing a graft very much akin to Brittain's method, by this surgical approach that Dr. Van Gorder has presented.

I have been very much impressed with the similarity of the roentgen appearance of the hip joint following Brittain's procedure and Dr. Van Gorder's procedure. The head of the femur and the trochanter have undergone marked osteoporosis in all Dr. Van Gorder's cases, showing something that I think is most important in the consideration of the value of the extra-articular operative procedure over the intra-articular procedure in tuberculosis of the hip. There is obvious evidence, by the marked atrophy which has occurred in the structures above the graft, that the graft immediately relieves all pressure and all weight-bearing in the hip joint itself. The architectural principle, as Brittain has called it, of the dome taking the stress and strain over onto the ischium, must be of great value in the healing of the tuberculous process.

The surgeon need not fear operative exposure of a tuberculous joint any more in the hip than he does in the knee. We developed a relatively simple operative procedure in 1929 for tuberculosis of the hip. We remove the crest of the ilium, split the anterior part of the ilium to the acetabulum and open it up widely like a book, then turn the excised fragment of the whole cortex of the ilium about 180 degrees. The proximal portion becomes the distal portion, so that the natural curve of the iliac crest allows it to fit into a prepared slot in the intertrochanteric region and head and neck of the femur; then it is thrust into the leaves of this separated ilium and held securely in position by the automatic compression of the separated iliac halves. We also do an intra-articular removal of cartilage in disease without dislocating the hip. However, we have had to wait for a period when the lesion was quiescent and, for many cases, this was a number of years. It seems to me that Dr. Van Gorder's operation could be done without the long period of waiting which we have had in our cases.

Incidentally, the results of our arthrodeses in tuberculosis and the results reported by Dr. Alan Smith in a previous paper on tuberculosis were 66 per cent. The results of those reported by Dr. Van Gorder are 100 per cent. So I must say I am a convert to the principle of extra-articular fusion by Van Gorder's method in tuberculosis of the hip, and possibly in many other conditions, when you do not want to run the danger of lighting up the infection.

I am sorry time does not permit discussion of Dr. Smith's paper.

DR. ALBERTO INCLÁN, HAVANA, CUBA: Fusion of the hip is frequently discussed, due to the fact that none of the numerous operations devised for this purpose is entirely satisfactory.

The papers presented by Dr. Van Gorder and Dr. Alan Smith are proof of the preceding statement. Dr. Van Gorder has offered the results of his experience with the revival of a little-known operation for extra-articular hip fusion,—namely, Trumble's ischiofemoral arthrodesis; while Dr. Smith has presented a new technique for intra-articular fusion of the hip, involving intrapelvic nailing of the iliac bone to the head of the femur.

In reference to Dr. Van Gorder's paper, ischiofemoral arthrodesis, with a bone graft to bridge the gap between ischium and femur, was used long before Trumble published his first paper in 1932. Maragliano first reported this technique in 1919. The Trumble operation appears to be a much more elaborate procedure than Brittain's technique for ischiofemoral fusion. The latter procedure has been employed by Dr. Inclán, Jr., on my Service for the past two and one-half years, in children, adolescents, and adults.

In the copy of Dr. Van Gorder's paper, which he kindly forwarded to me, no statement was made con-

cerning the ages of the various patients operated upon. This we consider of importance, since the percentage of fusions obtained is considerably lower in children, regardless of the technique used. We have also found that proper placement of the graft obliquely from below upward, and internal displacement of the femoral shaft, shortening of the gap between femur and ischium, and suppressing the sheering effect of weight-bearing, are conducive to solid fusion, with secondary hypertrophy of the graft. We have employed Brittain's technique, with certain modifications, in sixteen cases. Although favorably impressed by it, we feel that we need more cases and a longer follow-up period before rendering any conclusions. However, we consider Brittain's technique preferable to Trumble's, because of its simplicity and the fact that a medial displacement of the weight-bearing line occurs, due to the internal shifting of the femoral shaft. At the present time we consider it the operation of choice for the extra-articular fusion of tuberculous hips.

In discussing Dr. Alan Smith's paper on intra-articular fusion of the hip for osteo-arthritis and similar conditions, I congratulate him on being able to nail those hips from within the pelvis. It seems to me a major procedure, involving extensive dissection of articular and periarticular tissues. The reflection of the iliacus muscle may explain the relatively high incidence of thrombophlebitis which he has reported.

In the type of case described by Dr. Smith, we have been employing a combined surgical procedure, securing fixation by a long Smith-Petersen nail driven through the neck and head of the femur high into the ilium (as advocated by Watson-Jones), and depending for fusion on a sliding graft, taken from the outer cortex of the ilium, and placed between the ilium and the greater trochanter.

A Vitallium screw holds the end of the graft firmly in apposition with the raw surface of the iliac bone, just proximal to the rim of the acetabulum. The articular capsule may be excised, and the graft placed in direct contact with the freshened superior surface of the head and neck of the femur. This technique has given satisfactory results in the limited number of cases in which we have employed it. No postoperative plaster-cast immobilization is utilized, and the patients may be up in wheelchairs a week following operation and may walk on crutches four weeks afterward.

I congratulate the authors for their excellent contributions to the solution of the difficult problem of hip fusion.

DR. VAN GORDER (closing): I want to thank Dr. Badgley and Dr. Inclán for their kind criticisms of my paper, and to make one correction regarding the chronology of the Trumble operation.

It is not a more recent operation than the Brittain procedure, as was implied by Dr. Badgley, but was performed nine years before the Brittain operation. In fact, Brittain himself stated in his book (Architectural Principles in Arthrodesis, Baltimore, Williams and Wilkins Co., 1942) that his hip operation was based on the "ingenious ischiofemoral arthrodesis" of Trumble.

The Trumble operation differs fom the Brittain operation, however, in two important respects: (1) The femur is not osteotomized and (2) the operation is not blind.

If the Trumble operation is successful in fusing the hip, as it appears to be, the thought must surely arise: Why is it necessary or wise to go to the trouble and danger of fracturing the patient's femur in order to establish a bony ridge between the ischium and the femur, when this same end can be accomplished much more accurately, much more safely, and with much less trauma by the operation here described?

The extent of trauma associated with the Brittain procedure apparently varies considerably, as is natural in any blind procedure. For instance, Brittain quotes McMurray as stating that there is more shock after the Brittain operation than after any other method of arthrodesis. Although Brittain himself states that just the opposite is true, nevertheless he has written (J. Bone and Joint Surg., **30-B**: 642–650, Nov. 1948): "Some oozing always takes place, and sometimes it may appear alarming. If the anterior pelvic brim is traversed, the obturator artery may be divided. In addition, one may divide branches of the lateral femoral circumflex artery taking part in the digital anastomosis, and there may be muscular oozing from dividing the iliopsoas and small muscle like the piriformis and obturators. None of this haemorrhage is serious, with the possible exception of that from the obturator artery in a debilitated patient. There is no doubt that oozing does take place and that it goes on after operation, so that it is wise to have blood transfusions readily available." If one adds to the arteries mentioned above that may be divided, the external iliac, which is known to have been perforated while this operation was performed, then the danger of working in the dark amid important structures, including the sciatic nerve, is all the more impressive.

One is forced to question seriously, therefore, the advisability or the justification of carrying out an ischiofemoral fusion of the hip blindly, when a successful open procedure is available.

SLIPPING OF THE UPPER FEMORAL EPIPHYSIS *

BY M. BECKETT HOWORTH, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Hospital, New York City

A study of seventy cases of slipping of the upper femoral epiphysis from the New York Orthopaedic Hospital was presented in 1931 [1]. Sixty-two additional cases, a total of 132, were presented in 1941 [2]. From 1941 until January 1947, 111 additional cases have been treated, a total of 243. A careful and complete analysis of these cases forms the basis for the following report.

PATHOLOGICAL FINDINGS

One hundred and sixty-nine hips were operated upon in various stages of the disease, and gross and microscopic studies of the pathological tissue were made. Sections from the synovial membrane, the periosteum and bone of the proximal portion of the neck, the epiphyseal disc, and the femoral head were studied.

In the *preslipping stage*, grossly the synovial membrane is swollen, oedematous, and hyperaemic, and there is villous formation. Similar, but milder, changes occur in the periosteum and capsule. No gross changes are seen in the head or acetabulum. Microscopic sections of the synovial membrane disclose oedema and hypervascularity, usually with perivascular lymphocytic infiltration, scattered plasma cells and wandering cells, and villi. Decalcification and hypervascularity are present at the junction of the neck and the epiphyseal disc.

In the *slipping stage*, the epiphysis is displaced downward and backward in relation to the femoral neck. Usually the epiphysis rotates into a varus position at the same time, but a valgus deformity was present in three hips. The slipping may be sudden or gradual, and often it occurs several times in succession. The epiphysis never becomes completely separated from the neck, but remains attached by periosteum and fibrous tissue, which grow over the exposed portion of the neck as the slipping occurs. This new tissue may be recognized by its bluish color, its softness and looseness, and the frequent presence of tiny islands of bare bone. The cartilaginous epiphyseal disc remains attached to the head, but is gradually absorbed and transformed into bone. Callus rapidly forms in the angle between the head and neck inferiorly and posteriorly, but is covered by a fold of hyperplastic and redundant synovial membrane. The articular cartilage of the head and acetabulum remains normal in appearance. There is rarely hemorrhage into the joint unless there has been violent manipulation. Microscopically, the soft-tissue changes are similar to those seen in the preslipping stage. There is separation between the epiphyseal disc and the neck, with degenerative changes in the disc cartilage and evidence of repair at the junction.

In the *healing stage*, the medial margin of the neck, exposed anteriorly and superiorly by the slipping, gradually becomes rounded; in addition, the callus inferiorly becomes incorporated with the neck, thus changing the contours of the neck. The epiphyseal disc is gradually absorbed, and bony union occurs between the epiphysis and the neck. The synovial membrane and periosteum become less vascular and oedematous, more scarred and inelastic. The inflammatory process usually subsides after several months, but spontaneous union of the epiphysis may require two or three years. If the head has been separated from the neck in the course of treatment, degenerative changes in the head are the rule.

In the *residual stage*, the lesion is healed and the epiphysis is solidly united to the neck

* Portion of paper read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

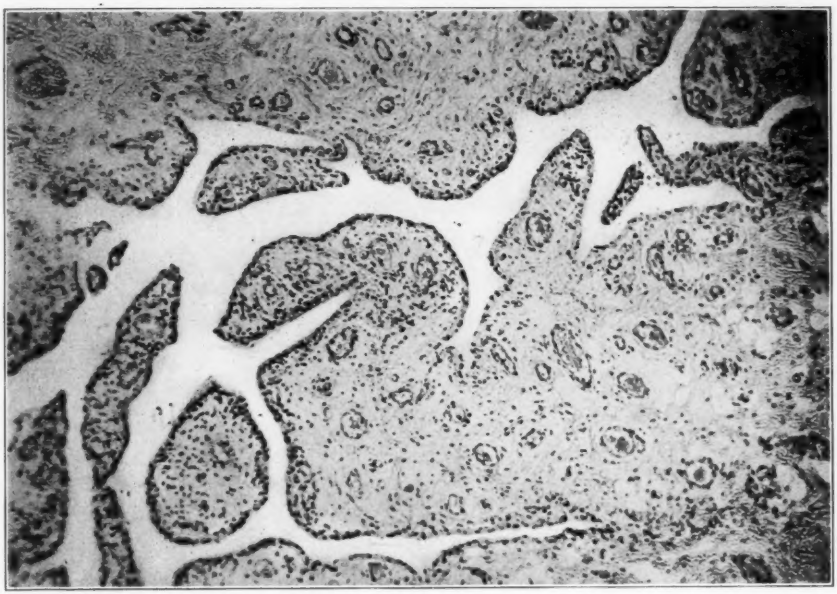

FIG. 1

Section of synovial membrane (× 50), taken at operation for pegging an epiphysis in the preslipping stage. Oedema, hypervascularity, villous formation, and a few plasma cells and small lymphocytes are visible.

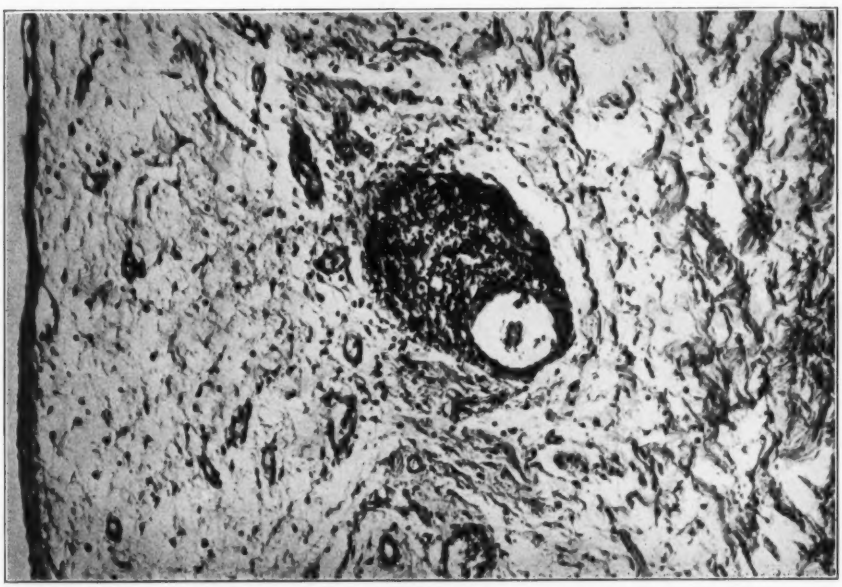

FIG. 2

Section of synovial membrane (× 100), taken at operation for pegging an epiphysis in the preslipping stage. Shows marked oedema and hypervascularity, with perivascular lymphocytic infiltration.

FIG. 3-A

Section taken from right epiphyseal plate (× 38), at operation for pegging an epiphysis in the pre-slipping stage. Shows degeneration and necrosis of fibrous tissue and cartilage.

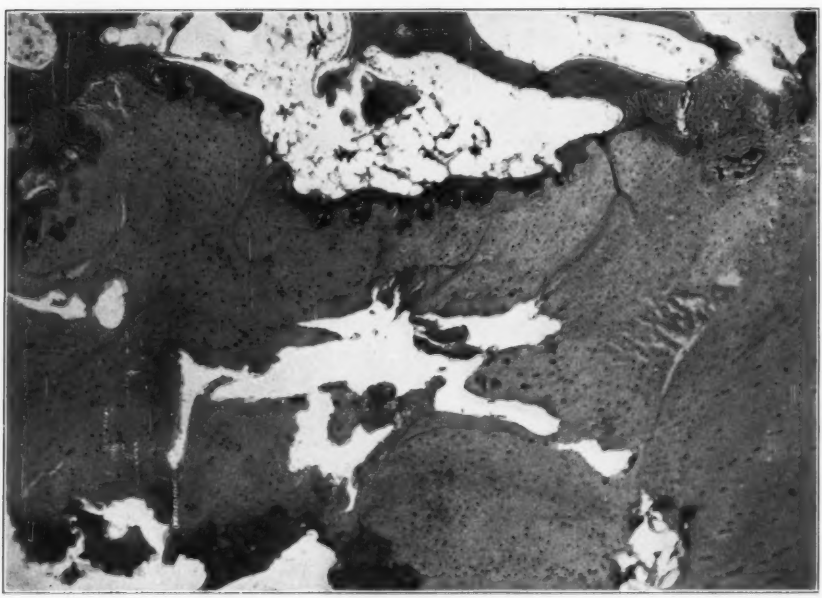

FIG. 3-B

Section taken from left epiphyseal plate (× 38), at operation for pegging an epiphysis in the pre-slipping stage. Degeneration, necrosis, and repair of fibrous tissue and cartilage are seen, with hemorrhage and foreign-body giant cells.

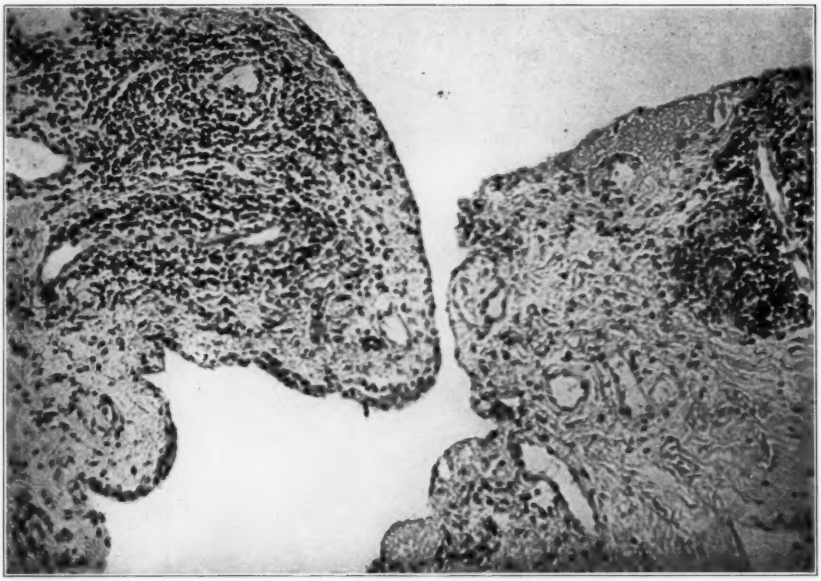

FIG. 4-A

Section of synovial membrane (× 100), taken at operation for open reduction of slipped epiphysis. Villi are present with focal lymphocytic infiltration, oedema, and hypervascularity.

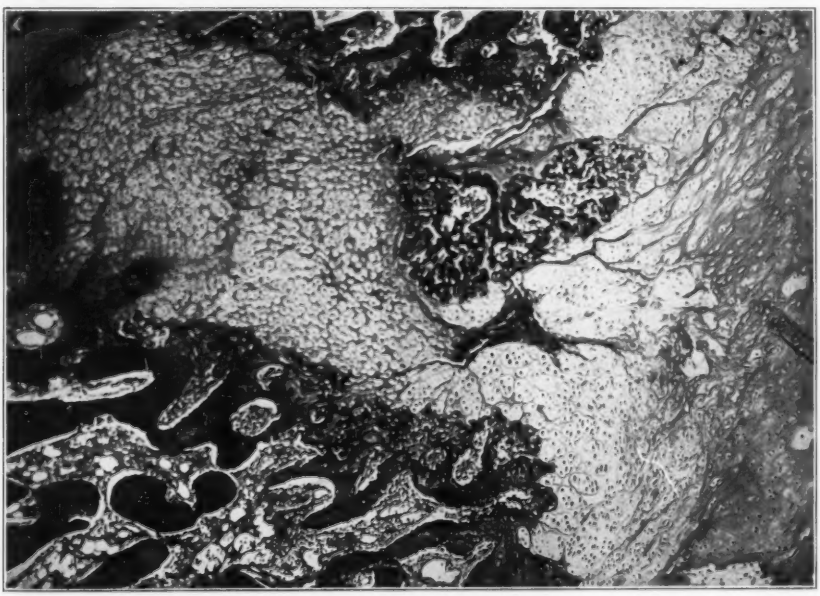

FIG. 4-B

Section of epiphyseal plate of same hip (× 38). Process of degeneration and repair can be seen at junction of plate with femoral neck; a mass of young cartilage cells is growing into a defect in the adjacent bone.

in the displaced position. The callus has become mature bone, indistinguishable from the neck itself, and the contours of the neck are smoother. The synovial membrane, the periosteum, and the capsule are sclerotic and inelastic. Osteo-arthritic changes develop if there is deformity, because of the faulty joint mechanics, especially if the joint is subject to strenuous activity or if there has been much damage to the circulation. Osteophytic production is often seen at the margin of the head and at the margin of the acetabulum.

TREATMENT

The results of the treatment for slipping of the upper femoral epiphysis should be

FIG. 5-A

C., a boy, aged thirteen years, had had pain and limp for one month. A bilateral pegging operation was done in the preslipping stage. An excellent clinical and roentgenographic result was obtained, with no degenerative changes,—the usual result after this operation.

On May 27, 1941, the epiphyseal lines were wide and irregular, with decalcification on the distal side. The capsules were swollen.

FIG. 5-B

June 3, 1941. In lateral views, very slight posterior displacement is seen. Pegging operation on left was done June 9; on right, October 20.

FIG. 5-C

Roentgenogram of right hip taken October 25, five days after operation; that of left hip taken August 11, nine weeks after operation.

FIG. 5-D

In lateral views taken on December 15, the epiphyseal lines had healed and were closing. The pegs were beginning to become absorbed. The heads and necks appeared healthy.

strictly evaluated in terms of the normal hip as to symptoms, signs, and roentgenographic appearance. The lesion always heals spontaneously, and treatment is of no value unless it produces a better result than would have been accomplished by nature. Too many reports of the results of treatment of this disease have failed to take these facts into consideration. The results in many cases which had no treatment have been better than those in similar cases after operation.

No Therapy

Although the lesion always heals, from one to three years are usually required and

there is the risk of considerable slipping, with deformity and its accompanying symptoms, and eventually osteo-arthritis. However, after healing, the symptoms and signs produced by the deformity are often found to be only slight and the disability negligible, until osteo-arthritis develops in middle life.

Endocrine Therapy

Thyroid has no appreciable effect on the lesion, and should be used only if there is definite hypothyroidism. Healing of the lesion and closure of all the epiphyses may be hastened by the administration of gonadal hormones, but limitation of growth and a telescoping of adolescence will result, with the possibility of disastrous psychological effects.

Bed Rest

The disease heals as a result of rest in bed, but many months may be required. The author has seen slipping occur after six months of bed rest. Slipping occurred in one boy's hip when he wrestled with his brother, while in bed. Bed rest or the avoidance of weight-bearing must be continued until the lesion is completely healed. After all pain and spasm have subsided, crutches may be used until the condition has fully healed, if the child can be trusted to avoid weight-bearing. An ankle sling attached to a Sam Browne type of belt may be used for suspending the leg, as in coxa plana, but the child with slipping of the epiphysis is often so large and the leg is so heavy that this method may not be practical.

Cast or Brace

Immobilization in a plaster cast or a brace is followed by relief of pain and spasm, and eventual healing of the lesion, but the period of healing may be several months or even two or three years, and there is considerable residual limitation of motion. If a brace is used, it should be of the non-weight-bearing type, with the affected extremity suspended in the brace and a built-up shoe worn on the opposite side; and it should be removed daily for active motion with the leg supported. Exercises in the pool or tank may be given later.

FIG. 5-E

On January 12, 1942, seven months after operation on left hip and three months after operation on right hip, the epiphyseal lines had closed and the pegs were being absorbed. The heads and necks were healthy.

FIG. 5-F

FIG. 5-G

By January 3, 1946, four and one-half years after operation, the epiphyseal lines had been obliterated and the pegs had been absorbed. The heads and necks appeared healthy. At this time displacement was negligible and there were no symptoms. The index of motion was 95.

Pegging Operation

The ideal treatment is to prevent slipping of the epiphysis and to hasten healing of the disease by the method which is simplest, safest, and quickest. For this purpose we have used, since 1930, an operation for inserting bone pegs across the epiphyseal plate. The operation may also be used after slipping has occurred. The hip joint is exposed anteriorly by a Smith-Petersen incision, and the capsule is incised close to and parallel with the rectus tendon. This exposes the junction of the head and neck, and the pathological condition can easily be studied. Much more of this area can be seen if the hip is moved slowly in various directions.

FIG. 6-A

FIG. 6-B

McC., a girl, aged fourteen years, had had pain and a limp for six months. The pegging operation was done for slight slipping. The clinical and roentgenographic result was excellent, with no degenerative changes,—the usual result from this operation.

Fig. 6-A: September 11, 1944. The epiphyseal line was slightly wide and irregular, with decalcification on the distal side. The capsule was swollen. Slight posterior displacement could be seen (lateral view).

The pegging operation was done on September 18.

Fig. 6-B: November 14. Eight weeks after operation, the epiphyseal line had healed and closed; the pegs were being absorbed. The head was healthy.

FIG. 6-C

April 19, 1945. Seven months after operation, the epiphyseal line and pegs were nearly obliterated. The head and neck were healthy.

Three years after operation, there was no further displacement; there were no symptoms; and the index of motion was 100.

With an osteotome, a triangular fenestration is made in the neck anteriorly, close to its junction with the head. Through this opening, three holes are drilled with a Nicola gouge in tripedal fashion, through the epiphyseal plate into the head. If there is posterior slipping, it is easier to drill the holes. It is important that the position of the head be clearly visualized and that the holes be drilled in the proper directions and to the proper depths. In three hips the operation failed because the fenestration was not close to the head, and the holes and pegs did not reach the epiphyseal disc. Three pegs are cut from the anterior portion of the wing of the ilium, each about one and one-half inches long and three-sixteenths of an inch in diameter, and inserted into the drill holes. It is important that the pegs not be fractured in the process of removal, as a fractured peg is more likely to be absorbed; failure in one case apparently resulted from this cause. After the pegs have been inserted, the fenestration is covered with a small piece of muscle to prevent bleeding and to favor smooth healing. The wound is sutured anatomically, and a flannel or elastic-bandage spica is applied.

The extremity may be suspended and light traction may be used for a few days, or a plaster boot may be applied with a crossbar to hold the hip in slight internal rotation, especially if there is slipping and a tendency to external rotation. The position of the pegs is checked by roentgenograms. Active motion with support is begun a day or two after the operation; and, in two or three weeks, motion has usually returned to the preoperative range. Walking is begun eight to twelve weeks after operation, with crutches for the first week or two, when the roentgenograms reveal healing of the lesion and beginning union of the epiphysis. Full activity, including sports, may be resumed four months after operation. There is usually solid union of the epiphysis within six months after the operation, and complete closure of the epiphyseal line within a year. This premature union of the epiphysis rarely results in more than one-fourth inch of shortening at this age period, and the shortening is usually negligible. The range of motion in the hip is essentially normal if there has been no slip, and there is no disability for any activity, including athletics.

FIG. 7-A

H., a girl, aged eleven years, had had symptoms for six months. The pegging operation was done for moderate displacement. A good clinical and roentgenographic result was obtained despite the displacement; there were no degenerative changes. This is the usual result after this operation, and is far better than would have been obtained by open reduction or osteotomy of the neck.

Fig. 7-A: March 20, 1946. The epiphyseal line was irregular, with a wide zone of irregular decalcification of the distal side. There was posterior displacement of one-half inch, with mature callus in the inferior angle between the head and neck.

On April 11 the pegging operation was done.

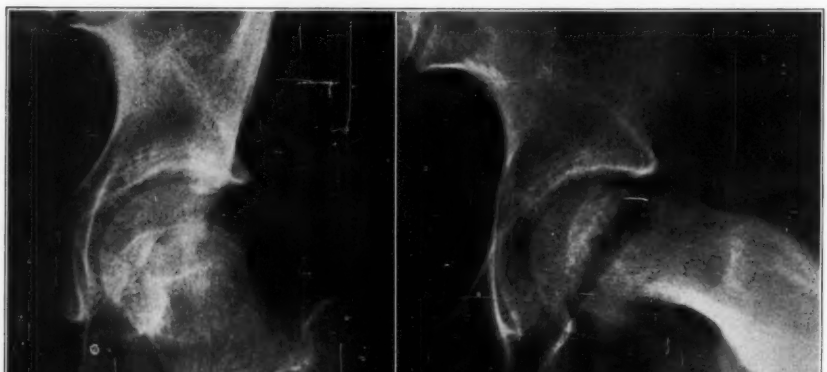

FIG. 7-B

September 10. Five months after operation, the epiphyseal line had healed and was closing; the pegs were being absorbed. The head was healthy; the proximal end of the neck was recalcifying.

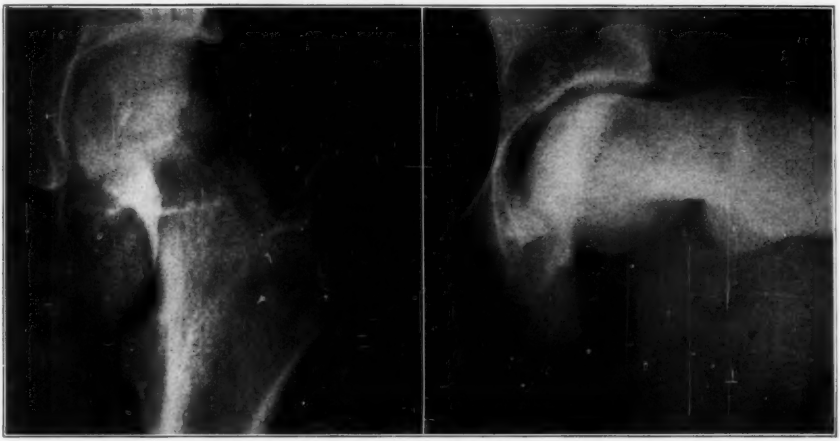

FIG. 7-C

In January 1949, almost three years after operation, the epiphyseal line and pegs were obliterated; the neck had recalcified; and the head and neck were healthy. There was no further displacement.

We have used the pegging operation on 134 hips; 120 cases were unilateral, and seven were bilateral. The youngest patient, a girl, was eight years old; the oldest, a boy, was seventeen. The operation was done in the preslipping stage on twenty-nine hips; after slipping had begun, on 102. The greatest amount of slipping was three-quarters of an inch. The first of these operations was done in 1930; the last in this series, in December 1946. The follow-up period ranged from one to seventeen years, with an average of seven years. Drilling alone, without pegs, was used in three of the hips. The epiphysis slipped in one of these, nine months later, and an open reduction was done; healing of the other two was quite slow and was not influenced by the drilling.

One failure resulted from absorption of the pegs, either because they were fractured in being removed from the ilium or because they were too small; the operation was repeated successfully. Three other failures occurred because the pegs did not reach the epiphyseal plate; the operations were repeated, with success. In no case did slipping occur after the pegging operation. The lesion always healed within three months, and the epiphyseal plate began to close shortly afterward. The clinical results have been excellent, with no pain, limp, or disability, even after strenuous athletics. The range of motion has been essentially normal if no slipping occurred. Internal rotation and sometimes flexion and abduction were proportionately limited if there was slipping. The shortening due to closure of the epiphyseal plate was negligible. There were no deaths and no deep wound infections. No arthritic lipping developed in the hips in which little or no slipping took place.

Nailing the Epiphysis

We have nailed the epiphysis with a Smith-Petersen nail, and have seen the results of nailing in several other series of cases. The nailing operation is simpler than the pegging operation (particularly for the surgeon who is accustomed to using the nail for fracture of the neck of the femur), largely because the approach is simpler. However, the danger of damage to the hip is greater, especially if the nail has to be driven in more than once, if it is driven too far, or if it does not remain wholly within the neck in its course to the head. Degenerative changes in the head and even in the acetabulum have occurred in many of the hips in which nailing was done, whereas no such changes were seen after pegging. Moreover, while a well-placed nail will prevent slipping of the epiphysis and will favor

eventual healing of the lesion and closure of the epiphyseal plate, the nail does not stimulate bone formation as do the pegs, and healing is slower. Early weight-bearing is sometimes possible when the nail is used and, although the immediate result may be good, the eventual result is less satisfactory. Wires may be used instead of the nail, with less likelihood of damage to the circulation at the hip or to the joint, but with a less stable fixation and no more rapid healing.

Reduction by Manipulation

We have attempted closed reduction in twenty-eight cases by forceful abduction and internal rotation. These hips were immobilized in plaster in abduction and internal rotation; and, while in this position, appeared to have at least partial reduction. However, when the casts were removed and proper roentgenograms were taken, it was found that complete reduction had been obtained in only two cases, partial reduction in four, and none in the remainder. Reduction failed because there was no way to hold the head and because of the resistance of the callus in the inferior angle. There was little or no callus and little displacement of the hips with a partially successful reduction.

The follow-up period ranged from one to ten years, averaging 4.5 years. Moderate permanent limitation of motion was present in most of the hips, probably due to immobilization during the inflammatory period. Degenerative changes of the head followed in several instances. Manipulative reduction should be reserved for those hips with recent slipping and no callus. If the displacement is corrected by closed manipulation, it is preferable to maintain the reduction with a nail rather than by immobilization in a plaster cast.

Reduction by Strong Traction

Strong manual traction, estimated at 500 pounds, combined with internal rotation and abduction, was employed in 1932 in an attempt to effect reduction in seven cases of slipped epiphysis with callus in the inferior angle. The downward displacement was corrected in most of these hips, but the posterior displacement usually was not corrected. All were immobilized in plaster for ten or twelve weeks. The eventual range of motion was poor in five cases, and good in only one. Degenerative changes followed in all but one hip, probably due to circulatory damage at the time of reduction, as well as to immobilization in plaster under tension. The results might have been better with nailing and active motion after reduction, rather than plaster.

Traction-Reduction with Nail Fixation

Closed reduction by manual traction, with the extremity in flexion and internal rotation (Leadbetter manoeuvre), was done in five cases within a few days after the slipping. The reduction was very good in three of the hips, and fair in two. Fixation was accomplished with the Smith-Petersen nail, and early active motion with support was begun a few days after the operation. Weight-bearing was started eight to ten weeks later. The follow-up period varied from four to seven years; the result was good in each case; and a good range of motion was maintained. The soft tissues evidently remain attached to the head in this type of reduction and the circulation is maintained, so that degenerative changes do not develop.

Open Reduction

Open reduction of the displaced epiphysis was done in thirty-one hips, the first in 1920, with anatomical improvement in all cases and excellent anatomical reposition in nearly all. It was necessary to separate the head from the neck in order to effect reduction, and usually to remove callus from the inferior angle. A nail was driven through the trochanter and neck into the head of one femur for internal fixation (1924). Twenty of the hips were immobilized in plaster for ten to twelve weeks. Good clinical results were ob-

tained in only two of these; one patient was only eight years old at the time of operation. Two cases were complete failures; one patient later had an arthroplasty and one a hip fusion. Marked limitation of motion and degenerative changes were the rule.

Internal fixation, with active motion from the first week, was used with open reduction in eleven cases. Fixation was obtained with the ordinary nail in two cases, with the Smith-Petersen nail in eight, and with the Lippmann screw in two. The anatomical result was usually good. The range of motion was better in this group than in the group having immobilization, the index ranging from seven to ninety-six, with an average of sixty-six. The worst results occurred in the two hips in which the nail had been driven through the head into the acetabulum. Degenerative changes occurred in four of the hips, and arthritic lipping was common in those cases followed for several years.

Osteotomy of the Neck

The deformity was corrected by osteotomy through the femoral neck in three cases, the first in 1925; and the hips were immobilized in plaster for about twelve weeks. These cases were reported in 1931. Considerable anatomical correction was obtained, but limitation of motion and degenerative changes were usual. Probably the results would have been better with internal fixation and early motion. However, in two later cases having osteotomy of the neck with fixation by a Smith-Petersen nail, and early motion, the results have been only fair.

Subtrochanteric Osteotomy

The deformity was corrected indirectly in ten hips, at least to some extent, by subtrochanteric osteotomy. The lower fragment was abducted and internally rotated. The operation was usually done in the residual stage. The hip was immobilized in plaster in seven cases, once with a long nail to prevent flexion of the upper fragment. Two of these hips became quite stiff. Internal fixation with a blade-plate was used in two cases, with early motion, and Russell traction in one. The position of the hip was usually improved; but, in several cases treated by immobilization in plaster in extension, flexion of the upper fragment resulted in further deformity and shortening. Supracondylar osteotomy for correction of external-rotation deformity was used for one hip, with success. Subtrochanteric or supracondylar osteotomy is much less likely to result in damage to the circulation of the hip and degenerative changes than is closed or open reduction or osteotomy of the neck, but the position of the fragments cannot easily be controlled.

CONCLUSIONS

The hip should never be held in a position of tension, especially extension, abduction, and internal rotation, as this wrings out the blood vessels along the neck and still further embarrasses the circulation.

No operation should be done when acute pain and spasm are present, at least until after two or three weeks of bed rest. The treatment of choice is pegging of the epiphysis in the preslipping stage or before much slipping has occurred. The results of this operation have been excellent, and far better than with any of the other methods of treatment. Drilling without pegging has little or no effect on the course of the disease. Even the slipped epiphysis can be pegged, and the deformity can be corrected later by subtrochanteric osteotomy.

NOTE: For Discussion of this paper, see page 21 of this Volume of *The Journal* (January 1949).

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2. HOWORTH, M. B.: Slipping of the Upper Femoral Epiphysis. Surg., Gynec., and Obstet., **73**: 723–732, 1941.

END RESULTS IN PHYSIOLOGICAL BLOCKING OF FLAIL JOINTS *

BY ALBERTO INCLÁN, M.D., HAVANA, CUBA

Many surgical procedures have been described to limit the motion of certain joints in a given direction, and are classified under the general heading of *arthroereisis*, in contrast to *arthrodesis*, in which all joint motion is abolished. The relative importance of this type of surgical technique may be gauged from the fact that it was one of the two principal subjects discussed at the Third International Congress of Orthopaedic Surgery, held at Bologna and Rome in 1936, under the inspiring presidency of the late Vittorio Putti.

The first arthroereisis or joint-blocking operation was performed by Wollenberg, in 1912, for genu recurvatum. Toupet, in 1919, performed the first posterior block of the ankle. Since then many other surgeons have added new joint-blocking techniques to our surgical armamentarium, such as those of Putti, Campbell, Ombrédanne, Nové-Josserand, Camera, Salaverry, and others for the ankle joint, and those of Campbell and Mayer for the knee.

Other techniques, which utilize various intra-articular and para-articular soft structures and tendons in the manner of check ligaments, have been employed in an attempt to limit abnormal joint motion. It is our belief that, although these procedures may be successful in mild cases showing no alterations in joint configuration, they fall short of their goal in more severe cases, when growth and increasing weight throw a greater stress on joints and ligaments, resulting in a recurrence of abnormal motion.

Most techniques devised for joint-blocking depend upon the placing of bone grafts in such a way that they will mechanically impede the excursion of the joint in a certain direction. This type of operation has been accompanied by such a high incidence of functional failure, due to absorption, fracture, or atrophy of the graft with a recurrence of abnormal motion, or to painful joint motion from secondary osteo-arthritis, that Branch, reviewing eighteen cases of posterior bone block of the ankle in 1939, stated: "The author hesitates to present a destructive paper such as this with no constructive criticism".

In an endeavor to secure a more physiological blocking of joints, altering the position of the joint surfaces themselves rather than blocking joint motion mechanically by means of grafts, the author has, since 1936, been employing the technique to be described. No originality is claimed; the principle is not new, and was embodied in techniques described by Putti in his second operation for anterior blocking of the ankle, by Bruce Gill in his operation for posterior ankle block, and by Lexer and Brett in their operation for genu recurvatum. This principle, however, has not been accorded proper emphasis by previous writers. It may be stated as consisting in the altering of the joint configuration in such a way that the range of motion is shortened without the introduction of a mechanical obstacle to normal excursion. This type of joint-blocking is termed "physiological", since the normal anatomical structures which make up the joint are not changed in substance, but are merely altered in their relation to one another. A perusal of the techniques to be described will clarify this concept.

Posterior Physiological Blocking of the Ankle

The operation is used in cases of paralytic drop-foot. A stabilizing triple arthrodesis of the talonavicular, talocalcaneal, and calcaneocuboid joints is first carried out, with resection of the head of the talus and correction of any varus or valgus deformities which may be present. While the next step is being performed, an assistant prepares the resected head of the talus, denuding one-half of the articular surface of cartilage and cutting a notch

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 4, 1948.

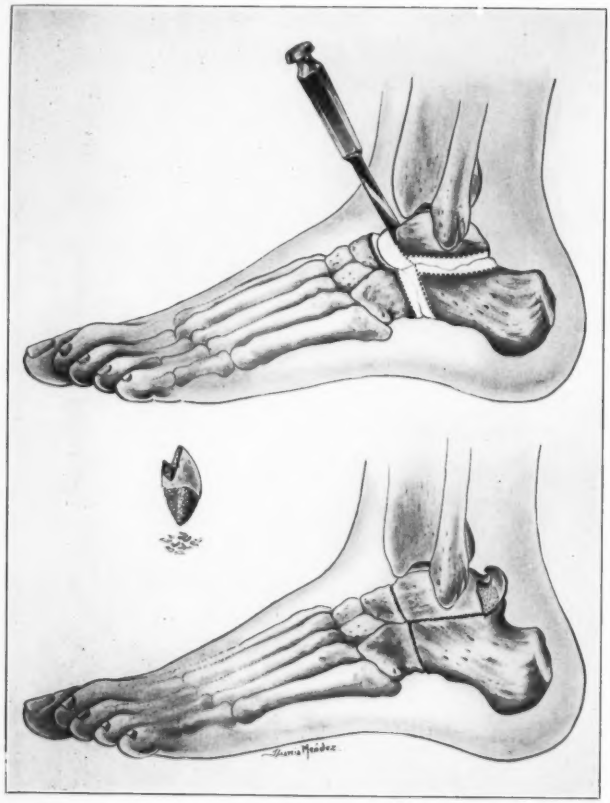

FIG. 1

Fig. 1: Physiological arthroereisis for paralytic drop-foot, according to author's technique. An osteochondral flap is raised from the posterior

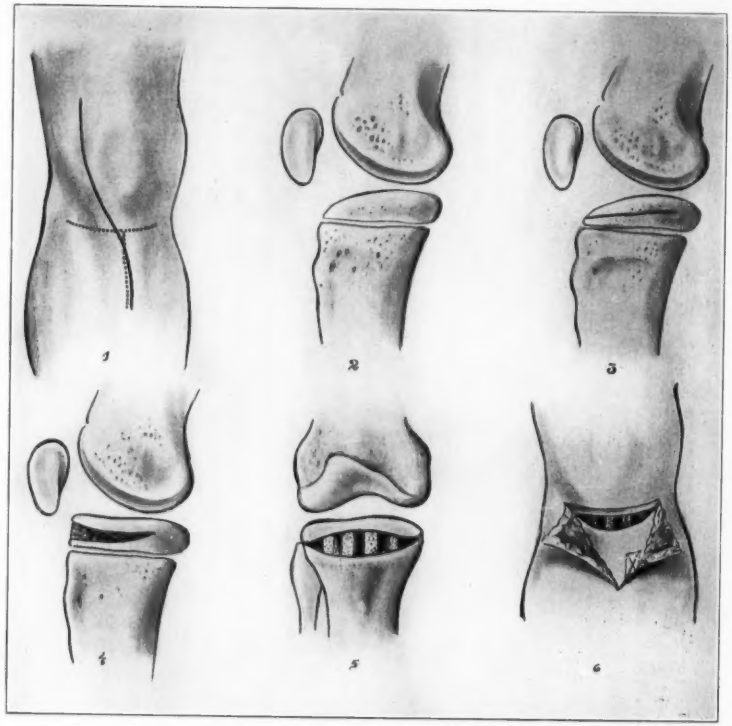

FIG. 2

Fig. 1 (*continued*): surface of the talus, and is maintained by the head of the talus, which is shaped like a cock's comb, thus modifying the articular surface so as to block plantar flexion. (Reproduced, by permission, from *Cirugía Ortopédica y Traumatología.*)

Fig. 2: Physiological arthroereisis of the knee joint to correct genu recurvatum. Schematic illustration shows the different steps of the operation according to author's technique. (Reproduced, by permission, from *Cirugía Ortopédica y Traumatología.*)

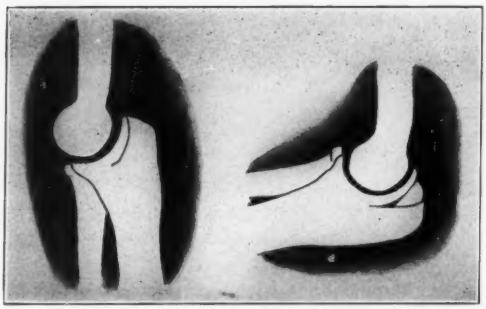

FIG. 3

Schematic illustration of operative procedure for posterior blocking of the elbow.

into the other half, so that the head of the talus assumes a shape reminiscent of a cock's comb (Fig. 1). Following triple arthrodesis and closure of the operative wound, the patient is turned into the prone position, and a posterior longitudinal incision is made, parallel to the Achilles tendon. The tendon is exposed and split by the Hoke Z-plasty technique, after which the underlying fat and ligamentous structures are split to expose the posterior surface of the talus and the superior surface of the calcaneus. With the foot held in strong dorsiflexion, a curved osteotome is driven forward, just under the superior articular cartilage of the talus, and used as a lever to raise an osteocartilaginous flap. While this flap is held in the raised position by the osteotome, a curved or angulated gouge is used to cut a deep vertical groove in the posterior surface of the talus and to raise a cortical flap from the superior surface of the calcaneus. The previously prepared head of the talus is then placed in this bed, its denuded portion in contact with the raw surfaces of the talus and calcaneus, and its notch holding up the osteocartilaginous flap, which is lowered into it after the curved osteotome has been removed. This elevation of the posterior portion of the superior articular surface of the talus effectively limits plantar flexion to about 10 degrees. Although a portion of the head of the talus projects upward and posteriorly, it has no blocking action, and may be fractured or resorbed without in any way influencing the final results.

Anterior Physiological Blocking of the Ankle

A corrective tarsal arthrodesis is first performed to correct the calcaneus or calcaneocavus deformity which may be present. The anterior portion of the superior articular surface of the talus is raised with an osteotome, and four wedges of bone, fashioned from the resected head of the talus, are placed under this osteocartilaginous flap to hold it up. The outer portion of the flap must be raised much higher than the inner portion, if its blocking action is to be maintained when the foot is dorsiflexed while in the pronated or abducted position.

TABLE I

PHYSIOLOGICAL BLOCKING OF FLAIL JOINTS

Operation	No. of Cases	Cases with Follow-up (*No.*)	(*Per cent.*)
Posterior blocking of ankle	102	51	50
Anterior blocking of ankle	30	10	33
Anterior blocking of knee	8	6	75
Posterior blocking of elbow	1	1	100
Totals	141	68	

Anterior Physiological Blocking of the Knee for Genu Recurvatum

A T-shaped incision is made, its horizontal portion just below the articular line of the knee joint, and its vertical limb along the anteromedial surface of the tibia. The articular

TABLE II

LENGTH OF FOLLOW-UP PERIOD IN SIXTY-EIGHT CASES

Time	No. of Cases
6 months to 1 year	3
1 to 5 years	37
6 to 10 years	18
11 years or more	10
Total	68

cartilage, with one-eighth of an inch of the underlying cancellous bone, is raised by an osteotome, driven from in front backward. A curved osteotome is used to develop this flap posteriorly, until the osteotomy almost reaches the posterior surface of the tibia. With the curved osteotome, this osteocartilaginous flap is then bent upward, conforming to the curved surfaces of the femoral condyles (Fig. 2). Four wedges of bone, taken from the tibia

TABLE III

FINAL RESULTS AND LATE COMPLICATIONS IN FIFTY-ONE CASES OF POSTERIOR PHYSIOLOGICAL BLOCKING OF THE ANKLE

Classification	No. of Cases	Per cent.	Plantar Flexion Possible (*Degrees*)	Complications *	No. of Cases	Per cent.
Excellent	24	47	10 to 12	Foot deformity	8	16
Good	20	39	13 to 15	Absorption or fracture of head of talus	7	14
Fair	6	12	16 to 20	Absorption and partial loss of blocking	2	4
Poor	1	2	21 or more	Hypercorrection, resulting in slight calcaneus	1	2
				Pulmonary and hip tuberculosis	1	2

* No instances of ankylosis of the ankle, infection, arthritic changes, or arthritic pain were observed.

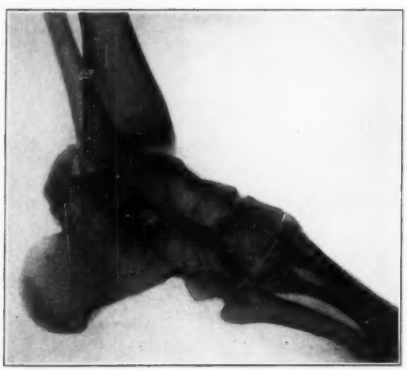

FIG. 4

FIG. 5

Fig. 4: Roentgenographic aspect of paralytic drop-foot, ten years after operation. By modification of the articular surface of the talus, blocking mechanism has been set up. No arthritic changes are evident.

Fig. 5: Roentgenographic aspect of paralytic drop-foot, eight years after operation. That portion of the head of the talus shaped as a cock's comb has been fractured; the blocking effect is maintained by the modified articular surface of the posterior aspect of the talus.

TABLE IV

FINAL RESULTS AND LATE COMPLICATIONS IN TEN CASES OF ANTERIOR PHYSIOLOGICAL BLOCKING OF THE ANKLE

Classification	No. of Cases	Per cent.	Dorsiflexion Possible (*Degrees*)
Excellent	5	50	10 to 12
Good	2	20	13 to 15
Fair	2	20	16 to 20
Poor	1	10	Over 20

Complications *	No. of Cases	Per cent.
Partial loss of blocking effect (4 to 10 degrees)	2	20
Total loss of blocking effect	1	10
Revision of arthrodesis necessary	1	10
Death from pulmonary tuberculosis, 2 years after operation	1	10

* No instances of infection, arthritic changes, pain on weight-bearing or walking, or ankylosis of the ankle were observed.

and inserted into the osteotomy site, hold the flap in place. This technique has been used successfully in the author's last six cases. In the first two cases a parapatellar incision was utilized, and the grafts were obtained from the patella. We have found cortical grafts from the tibia to be stronger and more suitable.

Physiological Posterior Blocking of the Elbow

A posterolateral incision is begun two inches above the tip of the olecranon process, and is carried along the lateral border of the process to its base. The tendon of the triceps is split in the mid-line, and the semilunar notch of the ulna is visualized. An osteotomy is begun just posterior to the upper border of the articular cartilage, the osteotome being driven downward, parallel to the cartilage. The elbow is flexed to 90 degrees, and the flap is raised until it blocks further extension of the joint. A wedge of bone, taken from the tibia, is inserted into the angle of the osteotomy to maintain the elevated position of the flap (Fig. 3).

COMMENT

The author recommends the surgical procedures described for blocking joints because of the following reasons:

1. The normal structure of the joint remains unaltered.
2. Limitation of motion is obtained without disturbing the

FIG. 6-A FIG. 6-B

FIG. 7-A FIG. 7-B

Fig. 6-A: J. W. Patient with paralytic drop-foot, before operation.

Fig. 6-B: Demonstrating appearance and blocking effect after operation on the left foot by the author's technique.

Figs. 7-A and 7-B: P. S. Photographs of a patient with extreme paralytic genu recurvatum, before and after operation.

TABLE V

FINAL RESULTS AND LATE COMPLICATIONS IN SIX CASES OF ANTERIOR PHYSIOLOGICAL BLOCKING OF THE KNEE

Classification	No. of Cases	Per cent.	Hyperextension Possible (*Degrees*)	Complications	No. of Cases	Per cent.
Excellent	3	50	10 or less	Limitation of normal joint extension	1	16.6
Good	2	33	11 to 15	Infection	0	
Fair	0		16 to 20	Ankylosis of the knee	0	
Poor	1	17	Extension limited	Arthritic changes in the knee	0	

TABLE VI

FINAL RESULTS AND LATE COMPLICATIONS IN SIXTY-EIGHT CASES OF PHYSIOLOGICAL BLOCKING OF JOINTS

Classification	No. of Cases	Per cent.	Complications *	No. of Cases	Per cent.
Excellent	32	47.1	Postoperative deformity	10	14.7
Good	25	36.8	Partial loss of blocking	5	7.4
Fair	8	11.8	Overcorrection	2	2.9
Poor	3	4.4	Late pulmonary tuberculosis	1	1.5

* No instances of joint ankylosis, infection, arthritic changes, or arthritic pain were observed.

normal joint mechanism and its anatomy by the introduction of extraneous blocking elements.

3. The procedures may be carried out without damage to the joint itself.

4. The epiphyseal cartilages remain unharmed, future growth disturbances being thus avoided.

5. The blocking effect is more permanent than that obtained by other procedures, not based on the same principles.

STATISTICAL DATA

The end results of the first fifteen cases, in which anterior or posterior blocking of the ankle was carried out by the techniques already described, were presented by the author in 1938. A recent review of the statistics of the Poliomyelitis Service of the Mercedes Hospital has shown that, of the 781 operations carried out on the 1,123 patients registered, 141 were done by the author's techniques, to obtain physiological blocking of flail joints.

In ankle-blocking the end results in cases with an adequate follow-up were judged as follows:

Excellent: In this group solid triple arthrodesis of the tarsal joints was obtained; only 10 to 12 degrees of plantar flexion was possible; weight-bearing was normal; and there was no pain on walking or motion.

Good: These patients had plantar flexion of between 12 and 15 degrees; the heel was not prominent, but weight-bearing was otherwise normal; and no pain was present on motion or weight-bearing.

Fair: In these cases plantar flexion, varying between 15 and 20 degrees, was possible; a tendency to varus or valgus deformity was present; and there was no pain.

Poor: In this group the blocking effect was lost or plantar flexion was possible beyond 20 degrees. Complications included infection, osteo-arthritis of the ankle joint, deformity, ankylosis of the ankle, and pain on motion or weight-bearing.

Of the total number of joint-blocking operations performed in all joints by these techniques, the end results were good or excellent in 85 per cent. of the cases; in 4.4 per cent. they were poor. Only sixty-eight cases in which an adequate follow-up was possible are included in this total. Of these, twenty-eight patients had been operated upon from five to ten or more years ago. The statistical data are given in greater detail in Tables I to VI, inclusive.

CONCLUSIONS

End results, obtained after twelve years of experience with techniques devised for securing physiological blocking of flail joints, are presented. The author's aim is to demonstrate the advantages of these and similar techniques, which are based on physiological restriction of a specific joint motion by alteration of the anatomical position or configuration of the joint surface.

The physiological blocking operations performed at the ankle and knee have shown permanent satisfactory results, classified as either good or excellent, in 85 per cent. of cases for as long as twelve years following operation.

Postoperative infections, ankylosis, or arthritis did not occur in any of the cases in this series.

Late loss, either partial or complete, of the original blocking occurred in 7.4 per cent. of the cases reviewed.

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FRACTURES OF BOTH BONES OF THE FOREARM IN ADULTS *

BY ROBERT A. KNIGHT, M.D., AND GEORGE D. PURVIS, M.D., MEMPHIS, TENNESSEE

From the Campbell Clinic and the University of Tennessee, Memphis

Fractures of the shafts of both bones of the forearm present specific problems, in addition to those difficulties which are common to all fractures of shafts of the long bones. Besides the necessity for regaining length, apposition, and axial alignment, normal rotational alignment must be regained, if a good range of pronation and supination is to be recovered. The chances for the occurrence of malunion and non-union are greater, because of the difficulties in reducing and maintaining the reduction of two parallel bones in the presence of the pronating and supinating muscles, which have angulatory as well as rotatory influences. Because of these factors, the end results obtained in the treatment of these fractures have frequently left much to be desired, especially in adults where the compensatory growth changes of childhood are lacking, and where the ability to recover with an excellent functional result, in the face of only a fair anatomical result, is usually absent. The purpose of this study was to determine the results obtained in the treatment of these fractures in adults, to determine the causes of failure, and to make recommendations for the exact treatment of these fractures.

One hundred cases of fresh fractures of the shafts of both bones of the forearm in adults (over fifteen years of age) treated by the Staff of the Campbell Clinic were studied. Colles's fractures and fractures of the head of the radius and of the olecranon were excluded from the study. The cases were grouped into the following categories, according to the method of treatment employed:

Manipulation		41
Open reduction:		
Without rigid internal fixation	13	
With plates	20	
With primary bone grafts	15	
With intramedullary wires	11	59
Total cases		100

Because of the variation in types and levels of fractures, the frequent occurrence of soft-tissue injury, and the presence of fractures elsewhere in the extremity or the body, it has been impossible to arbitrarily set up criteria based upon such factors as limitation of motion, loss of strength, and pain, by which to evaluate the end results in each case. Thus, in some cases with extensive soft-tissue injury in addition to the fractures, when making the final evaluation, limitation of motion as the result of scarring or loss of muscle or nerve function must be taken into consideration.

In grouping the end results, the excellent and good results have been accepted as satisfactory, while the fair and poor results have been considered unsatisfactory.

Early in the study, it became apparent that rotational alignment had been given considerably less attention than axial alignment and end-to-end engagement, both at the time of initial reduction and in the evaluation of the end results. Rotational alignment of the radius following fractures of the forearm has been briefly mentioned in the literature, but it was not until 1945 that Evans offered an accurate method of determining the rotational alignment by roentgenograms; Evans strongly re-emphasized the fact that any degree of error in rotational reduction would be followed by a corresponding limitation of pronation and supination of the forearm. In the past, it has been advised that fractures

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1949.

of the proximal thirds of both bones of the forearm should be immobilized in supination, those of the middle third in mid-position, and those of the lower third in either pronation or mid-position. These positions were chosen because of the anatomical arrangement and balance of muscle pull of the pronators and supinators of the forearm at the various levels. All cases in this series were studied in accord with Evans's suggestion, the degree of residual rotational deformity of the proximal radial fragment being determined. In a high percentage of cases, limitation of forearm rotation was found to correspond closely to the residual bony rotational deformity. As the study progressed, it was found that the end results regarding pronation and supination could be predicted with a surprising degree of accuracy from a study of the roentgenograms alone.

Determination of the degree of rotation of the proximal radial fragment is based upon the distinctive configuration of the proximal portion of the radius, particularly that of the bicipital tuberosity, the relationship of its cancellous portion to the shaft of the radius, and the shape of the bicipital curve of the radius. A calibration chart of the normal must be made with the forearm in varying degrees of pronation and supination, to determine the rotational position of the proximal radial fragment.

Evans has suggested that the "tuberosity-view" roentgenograms be made with the following constant technique: An anteroposterior view of the elbow joint is taken with the tube tilted 20 degrees toward the olecranon. The tip of the olecranon is placed one-third of the way along the plate, with the elbow flexed to 90 degrees, care being taken that both condyles of the humerus are at the same level. In attempting a manipulative reduction of the fracture, a comparative "tuberosity view" of the opposite elbow should be made, if there is any question as to the rotational position of the proximal radial fragment. Reduction of the fracture is then performed with the forearm in the position of rotation which corresponds to that of the proximal radial fragment, since the rotation of this fragment cannot be controlled, and the distal fragment must be brought into alignment with it; after the reduction, the forearm is immobilized in that position. If an open reduction is to be performed, in a case in which the radial fracture is comminuted, arrangements should be made for x-rays to be taken with a portable machine during the operation, should any question of rotational alignment arise.

ANALYSIS OF RESULTS

The end results have been unsatisfactory in a relatively high percentage of cases of fractures of both bones of the forearm in adults. In general, unless gross limitation of motion, gross deformity, or pain were present, the patients had little or no complaint. Limitations of extremes of pronation and supination were usually accepted by the patient, since abduction and internal rotation at the shoulder adequately supplemented mild limitation of pronation; and adduction and external rotation of the shoulder supplemented, to a lesser extent, limitation of supination. (One patient, a typist, complained specifically of inability to pronate the forearm sufficiently to place the fingers on the keyboard.) Pain was not present unless union was incomplete, or unless there was excessive bone proliferation which resulted in a painful bone block to rotation.

Pronation was rarely limited to an appreciable degree, unless anterior angulation of the radius resulted in a bone block; supination, however, was limited very frequently, due to the following causes, listed in order of frequency: (1) residual supination of the proximal radial fragment, due to incomplete reduction; (2) narrowing of the interosseous space, due to appositional angulation of one or both bones; (3) residual posterior angulation of the ulnar fracture, forming a bone block; and (4) derangement of the inferior radio-ulnar joint.

Inferior radio-ulnar instability was found infrequently, despite the rather common finding of inferior radio-ulnar axial subluxation due to slight radial shortening. Clinical symptoms of pain and instability were ordinarily found only in the presence of apposi-

tional angulation of the radius or ulna, or of an associated fracture of the ulnar styloid process with non-union. In other words, a piston-like or axial subluxation of the inferior radio-ulnar joint was usually asymptomatic; but symptoms were present if there was anterior or posterior angulation of one of the two bones.

MANIPULATION

The results following manipulation were, in general, unsatisfactory. Of forty-one cases studied, there were three excellent, nine good, seventeen fair, and twelve poor results (or 29 per cent. satisfactory results and 71 per cent. unsatisfactory results). There were five cases of non-union, an incidence of 12 per cent.; in two of these, both bones were involved, and in three, the ulna alone was involved. Solid union required a longer period of time than is generally thought necessary, averaging four and one-half to five months. Narrowing of the interosseous space, angular deformity, and rotational deformity were present in a majority of the cases. It is obvious that better results would have followed open reduction and some form of internal fixation. In 60 per cent. of the cases, residual rotational deformity of from 25 to 60 degrees was present, the proximal radial fragment being supinated, with resulting proportional limitation of supination. This is true for fractures of the lower third, as well as for those of the middle third and upper third. In the lower third, the pull of the pronator quadratus resulted in appositional

FIG. 1-A
August 27, 1940

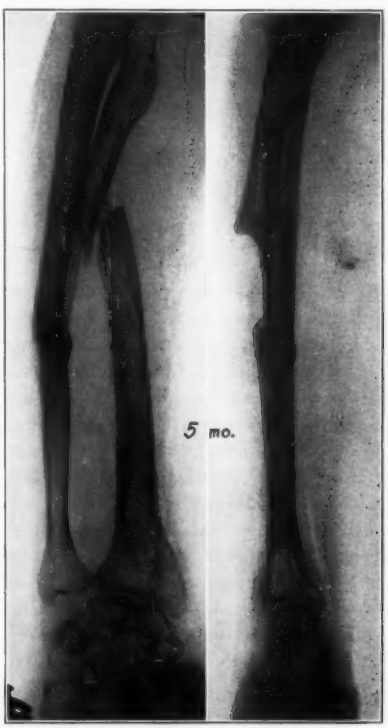

FIG. 1-B
January 31, 1941

Oblique fractures of the middle thirds of both bones of the forearm are shown. Manipulative reduction was unsatisfactory, because of failure to obtain engagement of the radial fracture or to correct rotational deformity of the radius of 90 degrees. There was subsequent loss of interosseous space; supination was absent. Primary open reduction of both fractures should have been done, with application of plates or onlay grafts.

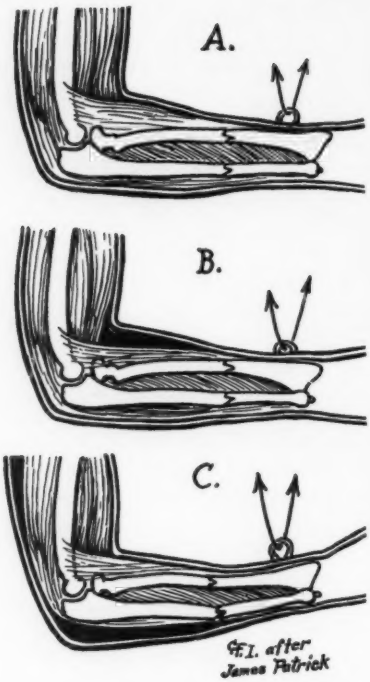

FIG. 2

Angulation of radius and ulna during period of cast immobilization is illustrated. *A:* Immediately after reduction, cast fits snugly. *B:* Atrophy of forearm muscles has taken place, with consequent loosening of cast in upper half of forearm. *C:* Cast has sagged while still holding distal fragments firmly, thus angulating radius and ulna. *D:* Method of suspending cast by sling, as advised by Patrick.

angulation, narrowing of the interosseous space, and a resultant loss of supination; in addition, the proximal radial fragment was usually in some degree of supination.

Fractures of the middle third also gave unsatisfactory results in most instances. It is even more difficult to obtain and maintain a satisfactory reduction in these and the fractures in the upper third and, if there is comminution or obliquity of one or both bones, open reduction is usually necessary (Figs. 1-A and 1-B). The rotational alignment must be checked, involving the making of comparative tuberosity-angle views of the opposite normal elbow, if necessary, so that the forearm may be reduced in the proper rotational alignment. If the fractures are transverse, an attempt at manipulative reduction appears justified; but, unless a stable anatomical reduction can be obtained, open reduction and internal fixation should be resorted to without delay.

No accurate correlation of rotational deformity to the level of fractures could be made; but it appears, from the results of this study, that, in most fractures of both bones of the forearm in adults, the arm should be immobilized in a position of supination following manipulative reduction.

Patrick pointed out that one of the causes for angulation of the radius during immobilization in plaster is that the weight of the cast is largely supported by a sling at the wrist (Fig. 2,*A*). The muscle bellies of the forearm are located chiefly in its upper half, while in the lower half the bones are largely surrounded by tendons. Consequently, as the muscles in the proximal half of the forearm become atrophied, the cast becomes loose and sags, while the distal halves of both bones remain relatively firmly immobilized, and consequently angulation may occur (Figs. 2,*B* and 2,*C*). Patrick advised that a sling be in-

FIG. 3-A
May 5, 1932

FIG. 3-B
October 4, 1932

Unsatisfactory result following open reduction of comminuted fractures in the middle third is shown. No internal fixation was applied to ulna; wire loop was applied to radius. Note residual rotational deformity of radius, approaching 90 degrees of supination.

corporated in the plaster just below the elbow, for suspension (Fig. 2,*D*). The authors have had no personal experience with this method, but Patrick has had no difficulty with the development of angulation of the radius since he adopted this method of cast suspension.

OPEN REDUCTION

Open Reduction without Rigid Internal Fixation

In earlier years, simple open reduction without internal fixation was employed, if the fractures were stable after reduction. If there was comminution or obliquity of either fracture, internal fixation, such as a figure-of-eight wire or a catgut suture, was placed across the fracture site. Thirteen cases in this series were treated by this method, with two good, six fair, and five poor results. In other words, approximately 85 per cent. of these were unsatisfactory. Angulation and displacement with associated cosmetic and functional disturbances of varying degrees were the cause of unsatisfactory results in most instances. Residual rotational deformity was present in several cases, despite the fact that the fractures were reduced under direct vision, emphasizing the fact that rotational alignment has not always been restored at the time of open reduction (Figs. 3-A and 3-B). In this group of thirteen cases, there were two instances of delayed union, and non-union of one or both bones occurred in six of the thirteen cases. This method of treatment would thus appear to be inadequate and unsatisfactory. If open reduction is performed, rigid internal fixation of both bones should be employed, even though the fragments can be firmly locked together by good serrations. End-to-end engagement alone will not guarantee maintenance of alignment.

Open Reduction and Plate Fixation

This method was employed in twenty instances with the following results: six excellent, one good, five fair, and eight poor (or 35 per cent. satisfactory results and 65 per cent. unsatisfactory results). In this group of twenty cases were two instances of delayed union of the ulna, one of delayed union of the ulna with non-union of the radius, and three of non-union of the ulna alone. These complications were the result of the use of plates or

FIG. 4-A
May 18, 1945

FIG. 4-B
June 8, 1945

FIG. 4-C
September 28, 1948

Primary onlay grafts to both bones, with excellent end result. Note screws used to transfix comminuted radial fragment. Consolidation was complete in twelve weeks.

FIG. 5-A
August 21, 1943

FIG. 5-B
September 7, 1943

FIG. 5-C
October 14, 1943

FIG. 5-D
January 4, 1944

Comminuted fractures of both bones. Primary onlay grafts have been applied, with accessory cancellous bone. Note failure to correct rotational deformity of radius of 80 degrees, and uncorrected narrowing of interosseous space. Accessory cancellous bone is a major factor in the production of synostosis.

screws of inadequate length, absorption at the fracture site, or failure of union of a comminuted fracture. The excellent results followed open reduction and plating of simple oblique or transverse fractures. In three of the twenty cases, residual rotational deformity of the radius occurred, despite reduction of the fracture under direct vision.

Open Reduction with Primary Onlay Grafts

Since 1942, in an effort to treat fractures of the shafts of both bones of the forearm in adults in a more definitive manner, primary onlay bone grafts have been used in selected cases. In the same year, Kellogg Speed reported its use.

Primary grafting has been employed in fifteen cases with six excellent results, three good results, one fair result, and five poor results. In all instances of fractures in the middle third, where onlay grafts were applied to both bones, satisfactory results were obtained (Figs. 4-A through 4-C). In two instances, a graft was applied to the ulna and a single screw was inserted across an oblique radial fracture; in both cases, the ulnar fracture healed satisfactorily, but the radial fracture angulated toward the ulna with resultant narrowing of the interosseous space and malunion. In three cases, where there was comminution of both bones in the proximal third, onlay grafts were applied and cancellous bone was placed about the fracture sites. In two of the three cases, both grafts fractured with resulting angulation and synostosis; in the third case, the grafts were applied with the radius in poor alignment and with narrowing of the interosseous space. Here, too, synostosis ensued (Figs. 5-A through 5-D). It is evident, first, that, if primary grafts are employed, they should be applied to both bones; and, second, that cancellous bone packed about the fracture site, particularly in fractures of the proximal third of the forearm, may lead to a synostosis. It is now advised that a "bone plate" of cortical bone be employed, the graft being at least six times the diameter of the shaft in length and two-thirds its diameter in width. It should be beveled at each end and fixed with four or more screws. Any large comminuted fragment should be fixed with an additional screw to either the proximal or the distal fragment.

In this series, homogenous bank bone has been employed in four instances; although the series is too small to permit any conclusions as to its value as compared with autogenous bone, the results have been as satisfactory. The use of bank bone makes a primary graft of both bones as simple a procedure and of no greater magnitude than the plating of both bones.

FIG. 6-A
February 21, 1947

FIG. 6-B
July 3, 1947

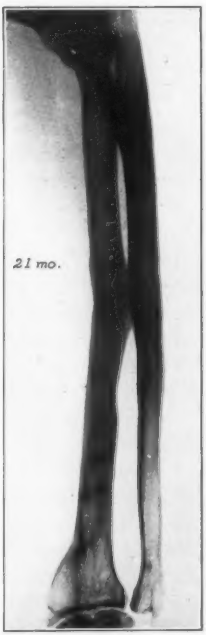

FIG. 6-C
November 27, 1948

Compound fractures of both bones with severe soft-tissue injury. Intramedullary fixation has not maintained anatomical position of radius, but has maintained good general position and alignment for secondary reconstructive procedures. The screws which are still present in the radius caused no symptoms and, at the patient's request, were not removed.

FIG. 7-A
August 24, 1947

FIG. 7-B
October 4, 1947

FIG. 7-C
March 19, 1948

Severe bone and soft-tissue injury. Ulnar wire should have been introduced farther down medullary canal and should not have been allowed to protrude through skin over olecranon. Wire was removed before consolidation was complete. Subsequent angulation of radius is not prevented by intramedullary Kirschner wire.

In the cases in which primary onlay bone grafts were employed, union was complete in an average of ten to twelve weeks. Thus, it would appear that consolidation takes place more rapidly following primary grafting than with the use of other methods.

Open Reduction and Intramedullary Fixation

Intramedullary wire fixation was used in eleven cases in this series; actually, it has been employed in a total of approximately thirty-five cases of forearm fractures, but the other cases were unsuitable for study because of inadequate follow-up. This form of treatment was used in those cases in which the forearms were severely traumatized and the fractures were comminuted, often presenting double fractures of either the radius or ulna (Figs. 6-A through 6-C). This form of fixation was used in these cases of segmental fracture because plating or grafting, even though otherwise feasible, would have required sufficient soft-tissue stripping to endanger the viability of the intermediate fragment. There were two excellent, three good, three fair, and three poor results in this group. The average time required for union was four and one-half to five months, comparable to the length of time required for union of fractures treated by manipulation. The causes of unsatisfactory results were: (1) failure to maintain correct rotational alignment of the radius; (2) angulation in cases where a single Kirschner wire was used in a double fracture of the radius; (3) angulation at the fracture sites, due to too early removal of internal and external fixation; and (4) non-union (Figs. 7-A through 7-C).

Although no definite evaluation of intramedullary fixation in forearm fractures can be made from these cases alone, our experience with the method has brought out several valuable points. The fixation afforded by an intramedullary wire or nail in ulnar fractures

is much more satisfactory than that in the radius, since its medullary canal is relatively straight and the wire or Küntscher nail can easily be inserted through the olecranon. The intramedullary wire or nail is inserted in the radius with difficulty, however, since it must be inserted through the radial styloid process or through a large drill hole on the dorsum of the radius in the vicinity of Lister's tubercle. The wire or nail must then pass into the medullary cavity obliquely; and, if it does not follow the normal curve of the bone, the radius will be straightened to some extent, with consequent narrowing of the interosseous space. The Kirschner wire has proved to be easy to insert, but does not have sufficient stability to prevent rotation or appositional angulation of the radius. This has been found particularly true in double or sectional fractures of the radius. In fractures of the lower third of the radius, the use of the Küntscher nail is practical, since the nail does not have to be introduced the entire length of the radius. However, in certain segmental fractures of the radius, it is safer to use intramedullary Kirschner wires, even though they do not perfectly maintain the fracture, than to strip the shaft of the radius the required extent for grafting or plating, with consequent risk of devitalizing a short segmental fragment. It is possible that the employment of two or more Kirschner wires, as utilized by Lambrinudi, may prove more satisfactory for maintaining radial fractures than a single wire.

Severe compound fractures can be fixed with intramedullary wires without markedly increasing the danger of dissemination of infection along the medullary canal or massive sequestration, if the fundamental surgical principles of thorough irrigation and débridement, followed by adequate chemotherapeutic and antibiotic therapy, are observed. Even in those cases in which non-union resulted, this method has had the advantage of maintaining length and alignment, greatly simplifying secondary reconstructive procedures.

Both internal and external fixation must be maintained until all fractures are shown roentgenographically to be consolidated, for clinical determination of consolidation is obviously unreliable. Despite the presence of intramedullary fixation, resumption of function before bony consolidation is complete may cause delayed union with excess callus formation or even non-union.

RECOMMENDATIONS

As a general rule, it is advocated that oblique or comminuted fractures of both bones of the forearm be treated by open reduction and internal fixation. Transverse fractures may be manipulated; but, if a stable reduction with anatomical alignment of all fragments cannot be obtained, one should then proceed to open reduction without delay. In fractures of the upper third, it is difficult to obtain anatomical alignment except by open reduction. When open reduction has been delayed, it is difficult to reduce the fractures, particularly as far as rotational alignment is concerned. If the fracture is reasonably fresh, the serrations of the bone ends can easily be fitted into their proper niches, to ensure correct rotational alignment. If there is comminution, a primary graft of proper size should be applied. In fractures of the lower third, it is recommended that some form of internal fixation be employed. An intramedullary ulnar wire introduced through the olecranon, and a Küntscher nail inserted into the radius from its distal portion, will maintain position and alignment adequately.

The approach employed in open reduction of the ulna presents no problem, since the bone is subcutaneous throughout its length. In the upper and middle thirds, the plate or graft should be applied to the dorsal surface of the bone, in order not to block pronation; while, in the lower third, the plate or graft should be placed on the volar surface, beneath the flexor muscles, rather than on a superficial surface. The approach to the radial shaft, however, is less simple. In the upper third, where the supinator must be elevated, the anterior approach of Henry permits easy elevation of the supinator muscle from its insertion, without endangering the deep branch of the radial nerve. In the middle third, the posterior approach of Thompson is suitable; or, if preferred, Henry's anterior approach

may be made. There is little danger of injuring a part of the radial nerve below the upper third, since the nerve is sensory in character distal to this point. In the lower third, the distal portion of Henry's approach, as advised by King, should be employed. An anterolateral incision is made over the lower third of the forearm, which permits application of the plate or graft on the flat flexor surface of the radius beneath the flexor muscles.

The screws should not protrude beyond the opposite cortex; the use of screws which are too long may cause irritation and limitation of supination or pronation.

When open reduction is done, a tourniquet should be used; before the incisions are closed, the tourniquet should be removed and hemostasis secured. This is advisable regardless of the site of fracture; but it is imperative, if the anterior approach of Henry to the upper third of the radius has been employed. In one case in this series, Volkmann's contracture resulted from failure to ligate the recurrent branch of the radial artery. In closing the wound, the deep fascia should be snugly sutured, in order to prevent depression of the operative scar. In all cases of fractures of the shafts of both bones of the forearm, a snug plaster-of-Paris cast, extending from the axilla to the distal palmar crease, with the elbow flexed to 90 degrees, should be employed until all fractures are shown to be consolidated, both clinically and roentgenographically.

CONCLUSIONS

1. An end-result study of 100 cases of fresh fractures of the shafts of both bones of the forearm in adults has revealed a high incidence of unsatisfactory results.

2. Improper rotational alignment is an important causative factor in a high percentage of poor results.

3. Transverse fractures in the middle and lower thirds of both bones of the forearm may, in some instances, be satisfactorily reduced by closed manipulation, if reduction is performed with correct rotational alignment.

4. Fractures of the upper third of the forearm, and oblique or comminuted fractures at any level in the forearm, are best treated by open reduction and rigid internal fixation of both bones.

5. Simple transverse and oblique fractures of the shafts may be plated; but comminuted fractures of the shafts are most satisfactorily treated by primary bone-grafting.

6. Intramedullary fixation is a very satisfactory method of maintaining the reduction and alignment of complicated fractures of the shafts of both bones of the forearm, particularly where there is major soft-tissue injury and where other methods of internal fixation, such as plating and primary grafting, are contra-indicated.

7. External plaster fixation must be maintained until union is clinically and roentgenographically complete, regardless of the type of internal fixation employed.

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THE EXPERIMENTAL PRODUCTION OF ECTOPIC CARTILAGE AND BONE IN THE MUSCLES OF RABBITS *

BY JOHN H. HEINEN, JR., M.D.,** G. H. DABBS, B.S., AND H. A. MASON, B.S., CHICAGO, ILLINOIS

From the Division of Orthopaedic Surgery of the Department of Surgery and from the Department of Physiology, University of Chicago

A specific osteogenetic substance has been hypothesized by several investigators in the last decade. Levander obtained cartilage or bone, or both, in 23 per cent. of seventy rabbits by injection of alcoholic extracts of autologous bone or fracture callus into the rectus femoris muscle. Injections into sixty animals of alcohol alone and into twenty animals of alcoholic extracts of connective tissue, striated, or smooth muscle, all yielded negative results.

Annersten demonstrated chondrogenesis or osteogenesis in half of the rabbits injected with concentrated homologous extracts and in one-fourth of those injected with heterologous extracts (calves' bones). On the basis of one positive result of ten tests with homologous extract of kidney, and one positive result of six tests with dialyzed urine of rabbits, Annersten supported the hypothesis of Levander that an osteogenetic substance circulates in the blood and is excreted by the kidneys. He obtained four positive results among a large series of controls.

Bertelsen compared alcoholic extracts of whole bone with those of marrow, cortex, epiphysis, and periosteum. In a total of sixty muscles in thirty-three rabbits, he obtained twenty-nine positive results (48 per cent.). Extracts of bone marrow were distinctly superior (83 per cent. positive) to the other fractions. Among forty-one control experiments with extracts of several tissues, one positive result was obtained with extract of liver.

Lacroix [11,12] obtained cartilage, bone, and hematopoietic marrow forty-one days after the injection of alcoholic extracts of epiphyses of newborn rabbits into the thigh muscles of other rabbits. He emphasized that his extracts of epiphyses that were largely cartilaginous produced chondro-osseous tissue which resembled more closely a bone than that obtained by other workers who had extracted bone or cartilage of older animals. He suggested that the hypothetical substance be called "osteogenin" and was challenged by Levander and Willstaedt, who claimed that prior discovery had been reported.

Rendano obtained cartilage in one of twenty-two rabbits with extracts of bone; six controls injected with 40 per cent. alcohol were negative.

Martin Lagos and Zarapico Romero obtained cartilage and bone, either alone or in combination, in seven of eighty-seven rabbits (8 per cent.) following injection of 40 per cent. alcohol into the rectus femoris. They concluded that the action of an osseous extract was not necessary for obtaining positive results.

Blum reported that injection of a mixture of phosphatase, glycerophosphate, and alginate gel into the rectus femoris of rabbits led to the formation of ectopic bone after thirty-five days, whereas no bone was obtained with the alginate gel alone.

The initial purpose of the present investigation was the substantiation of the results of Levander and of Annersten. When it became evident early in the course of the work that positive results could be obtained in an appreciable number of animals following injection of alcohol alone, the aim was redirected from a study of extracts to a study of the factors modifying the results with alcohol alone. Some animals were injected with calcium chloride, since the alginate gel-phosphatase mixtures of Blum contained this irritant. The investigative routine adopted and the results obtained are presented here.

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**Fellow in Orthopaedic Surgery of the National Research Council.

TABLE I.

EXP. NO.	INITIAL DATE	RABBIT NOS.	SEX M,F	AV. AGE MOS.	SUBSTANCE INJECTED	TRICEPS NO. MUSC.*	TRICEPS NO. POS.	QUADRICEPS NO. MUSC.	QUADRICEPS NO. POS.
3	9-8-46	24-37	5,9	3-4	EXTR. MUSC.	6	5	4	0
					EXTR. BONE	5	2	7	2
4	11-15-46	38-43	3,3	3-5	40% ALC.-HCL	6	6	6	0
5	2-28-46	44-49	3,3	5+	40% ALC.	6	2	5	0
					EXTR. BONE	6	2	6	1
6	2-6-47	50-53	3,1	2-	40% ALC.	3	2	3	1
					BLOOD	0	0	0	0
7	2-22-47	54-62	5,4	3-4	40% ALC.	7	4	8	2
					2% $CACL_2$	8	1	8	2
8	2-28-47	63-70	4,4	3	40% ALC.	7	3	8	2
					2% $CACL_2$	6	0	8	1
9	4-2-47	71-81	8,3	1-1 1/4	40% ALC.	8	6	10	7
					1% $CACL_2$	10	1	10	2
10	4-3-47	82-84	1,2	1-1 1/4	1% $CACL_2$	3	0	3	2
					1% NH_4CL	0	0	0	0

*CONTAINING MACROSCOPIC LESIONS NOT GROSSLY INFECTED.

Pos. = positive. Extr. = extract.

PROCEDURE

A summary of the experiments is given in Table I. Experiments 1 and 2, which are considered preliminary, are not included. The rabbits used were derived from mixed New Zealand and Flemish strains, and were maintained on a ration of complete rabbit chow, supplemented several times weekly with raw carrots and lettuce.

The substances injected were prepared as follows:

1. *Extracts:* The extracts used in Experiments 3 and 5 were prepared according to the method of Annersten. The long bones were excised from freshly killed rabbits (approximately three months old in Experiment 3, and five months old in Experiment 5), and were crushed to a pulp in a hand mill. A tissue mincer was used to prepare the pulp for the extracts of skeletal muscle. About 2.5 cubic centimeters of extraction fluid (100 cubic centimeters of 95 per cent. alcohol plus 5 cubic centimeters of tenth-normal hydrochloric acid) was added to each gram of pulp and the mixture was rotated in a gentle shaker for about twenty hours (some at room temperature, some at 1 degree centigrade). The mixture was centrifuged; the supernatant fluid was decanted and concentrated to about one-half its volume in an air stream at 32 to 35 degrees centigrade (Experiment 3) or in a vacuum desiccator (Experiment 5). In Experiment 5, the extract was passed through a

Seitz filter prior to concentration. The concentrated extracts were mixed with an equal volume of normal saline immediately before injection; from 3 to 5 cubic centimeters of this mixture per muscle was injected.

2. *Alcohol:* Commercial 95 per cent. ethanol was diluted to 40 per cent. by volume with sterile distilled water. In Experiment 4, the alcohol was acidified with hydrochloric acid (190 cubic centimeters of 40 per cent. alcohol plus 5 cubic centimeters of tenth-normal hydrochloric acid).

3. *Calcium Chloride:* One or 2 per cent. aqueous calcium chloride was sterilized by autoclaving.

4. *Autogenous Blood:* In Experiment 6, blood was obtained by sterile heart puncture, and was injected intramuscularly before it clotted.

5. *Ammonium Chloride:* Sterile 1 per cent. ammonium chloride was employed in Experiment 10.

The various substances were injected under sterile precautions by multiple-puncture infiltration into the triceps and quadriceps. A different 22-gauge needle was used for each muscle, and contact with the skeletal system was avoided. In Experiment 3, the needle was inserted mainly into the mid-portion of the muscle; in Experiments 4 and 5, mainly into the distal portion. In Experiments 6, 7, and 8, it was inserted in half of the animals in the mid-portion, in half, in the distal portion; while in Experiments 9 and 10, the single injection was made into the mid-portion. Although not specifically stated by Levander or Annersten, it is likely that the rectus femoris muscle which they injected was the second or posterior portion of the rectus femoris, as described by Bensley. Martin Lagos and Zarapico Romero, on the other hand, stated that they injected into the anterior rectus muscle of the thigh. We have in our later experiments attempted to infiltrate especially the second or posterior portion. However, it was evident from the extent of the lesions and from roentgenographic studies, made after intramuscular infiltration with radio-opaque material (diodrast), that considerable spread of the injected substance throughout the muscle occurs regardless of the primary site of injection. In view of this, the location of the lesions should be given more emphasis than the location of the injection site.

The duration was considered the period from the first injection (or pre-injection) of an irritant solution into the muscles to the time the muscles were excised. This period varied from nineteen to thirty days (with an average of twenty-five). The earlier and later stages of the reactions have not been studied in this investigation.

After sacrifice of the animals, the muscles were examined roentgenographically *in situ* and after excision. Transverse incisions were made about 5 to 8 millimeters apart and extending almost through the muscle. Fixation in Zenker-formol mixture for twenty-four hours was followed by washing for twenty-four hours in running tap water. Slices, 2 to 5 millimeters thick, were numbered consecutively from the insertion of the muscle. The slices were stored in 70 per cent. alcohol and placed in water for several hours prior to sectioning. Tissues which roentgenographically seemed to contain bone were usually decalcified in 6 per cent. sulphosalicylic acid for forty-eight hours, and then washed in water for twenty-four hours. From each slice, sections of about 25 to 50 micra in thickness were cut on a freezing microtome. These were mounted from 50 per cent. alcohol onto slides, previously covered with a thin film of 2 per cent. gelatin. The sections were stained with Wright's stain (1.5 grams of Wright's stain in 500 cubic centimeters of absolute methyl alcohol), dehydrated, cleared in xylol, and mounted in clarite.

RESULTS

The lesions were usually visible grossly as necrotic areas in the muscles, often chalky in appearance, firm to palpation, and opaque to transillumination. In some instances, discrete, hard nodules were palpable which proved to be chondro-osseous tissue. Gritty material frequently was encountered by the knife when slicing the fresh muscle.

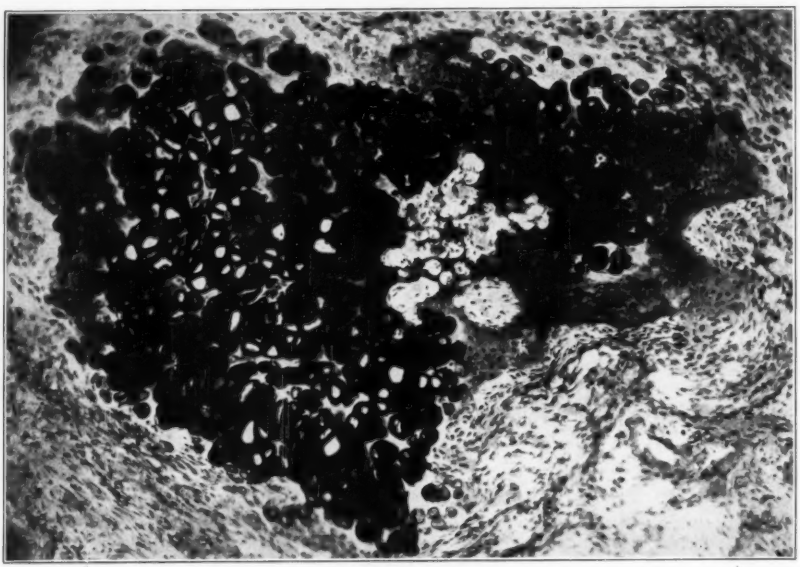

FIG. 1-A

Experiment 6, Rabbit 50. Cartilage occurring in the left triceps twenty-three days after a single injection of 40 per cent. alcohol (× 90). New bone can be observed at the lower right margin of the cartilage; endochondral replacement has begun in the central portion. Celloidin section, stained with hematoxylin and eosin.

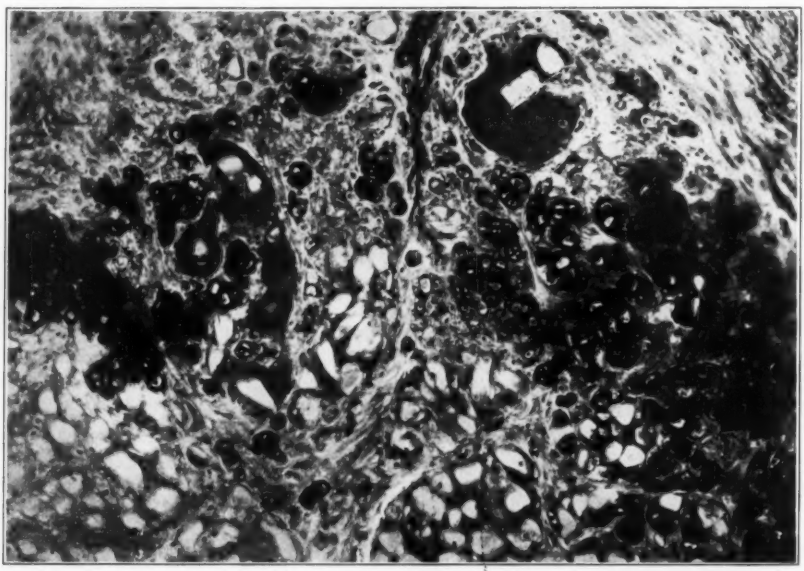

FIG. 1-B

Cartilage occurring in the left triceps of the same rabbit, twenty-three days after a single injection of 40 per cent. alcohol (× 110). Cartilage cells, often isolated, can be seen in the connective tissue between the muscle fibers. Celloidin section, stained with hematoxylin and eosin.

The histological appearance was that which is seen after the injection of any necrotizing or irritating solution. Centrally, in the more severely injured regions, the muscle fibers and the connective tissue lying between them were necrotic. No nuclei were visible in the pink-staining muscle fibers, and there was no evidence of proliferation of connective tissue here. Peripherally, where the damage was less, there was a widespread proliferation of connective tissue which extended between the muscle fibers. Here, some of the muscle fibers were necrotic and some were calcified; some showed multinucleate giant cells, while others appeared normal. Nodules of fibrous tissue, such as those seen in the organizing stage of granulation tissue, were observed frequently where the lesion had involved the fasciae, tendons, or larger intermuscular septa.

Cartilage occurred in the newly proliferated connective tissue, either as discrete nodules of hyaline cartilage (Fig. 1-A) or as aggregations of isolated, encapsulated cartilage cells (Fig. 1-B). The cartilage was situated between the muscle fibers, adjacent to the dense fasciae or tendons or, occasionally, within the dense fascia. Endochondral ossification was observed frequently. After injection with alcohol alone or with calcium chloride, intramuscular nodules of chondro-osseous tissue were produced (Fig. 2-B). Enchondral replacement of these cartilage nodules by bone may produce a structure resembling the cortex and medulla of a tubular bone. Hematopoietic and fatty marrow often are present.

Granular, crystalline deposits of lime salts, identified by the von Kossa method, were often observed. Such deposits were found in muscle fibers, in nodules of connective tissue, in the dense fasciae, and in the subcutaneous tissue. There appeared to be no mutual dependence between these deposits of lime salts and the newly formed cartilage and bone, although the two were occasionally observed in juxtaposition.

The reactions after injection of calcium chloride differed from those following alcohol (in the concentrations compared) mainly in the degree of necrosis. The calcium chloride produced more necrosis, and was followed by more intense calcification. No radio-opacity was observed immediately after infiltrating a muscle with 2 per cent. calcium chloride.

In Table I, the experiments have been summarized and the number of muscles satisfactorily injected (that is, without gross suppuration) have been compared with the number of muscles which were positive (that is, contained pre-cartilage, cartilage, or bone). After the injection of alcohol alone, twenty-three of thirty-seven triceps (62 per cent.) and twelve of forty quadriceps (30 per cent.) were positive. Two of twenty-seven triceps and seven of twenty-nine quadriceps were positive after injection of calcium chloride.

The relationship of the histological sections to the origin and insertions of the muscles is diagrammatically represented in Tables II and III, the location of cartilage and bone being superimposed upon the extent of the lesions. There was a greater tendency for pre-cartilage, cartilage, or bone to lie nearer to the origin and insertion of the muscles than in the mid-portion. No instance of direct connection of the newly formed bone with the skeleton was observed. While the tables depict only the muscles which were positive, there were many others with fibrous proliferation but not cartilage or bone formation.

In Experiments 9 and 10, the cartilage or bone which formed proximally in the muscles occurred more frequently in certain locations. In eight muscles (six rabbits), bone or cartilage was found in, or adjacent to, the posterior portion of the rectus femoris, next to the dense, vertical fibrous septum situated in the mid-portion of the muscle. Similarly, the fascia which surrounds the muscle was a favorite site for chondrification (Fig. 2-B). In six, cartilage or bone was located in the long head of the triceps. Five of these showed chondro-osseous metaplasia near the dense fascia on the medial border of the muscle.

The sex of the animals appeared to have no relationship to the incidence of pre-cartilage, cartilage, or bone formation. Satisfactory lesions (the various irritants listed in Table I being used) were produced in ninety-one muscles in male animals, with thirty positive results (33 per cent.). Of seventy-six muscles in females, twenty-six positive results (34 per cent.) were obtained.

TABLE 2.

EXP. NO.	RABBIT NO.	SEX	AGE - MONTHS	SIDE - R, L.	SUBSTANCE PRE-INJECTED	SUBSTANCE INJECTED	NO. INJECTIONS	EXERCISE	STILBESTROL	DURATION - DAYS	TRICEPS ← INSERTION ORIGIN → NUMBER OF MUSCLE-SLICE 1	2	3	4	5	6	7	8	9	10	11	12	13
3	24	F	3-4	L	-	EX. M.	3	-	-	23	C	C											
	26	M	"	L	-	EX. M.	"	-	-	23	C	PC											
	28	F	"	L	-	EX. M.	"	-	-	19	C												
	31	F	"	R	-	EX. B.	"	-	-	22	C	C	C										
	32	M	"	R	-	EX. B.	"	-	-	22	C												
	"	"	"	L	-	EX. M.	"	-	-	22	PC	C											
	37	F	"	L	-	EX. M.	"	-	-	22	PC	C	PC					N					
4	38	F	3-5	R	ALC.	AC. ALC	1	-	-	24		C	C	B									
	39	F	"	"	"	"	"	-	-	"	PC	PC											
	40	F	"	"	"	"	"	-	-	"		PC		PC									
	41	M	"	"	"	"	"	-	-	"	C	CB	C	C	PC								
	42	M	"	"	"	"	"	-	-	"	PC	C	C	C		PC							
	43	M	"	"	"	"	"	-	-	"	C	C											
5	44	F	5+	L	ALC.	ALC.	3	-	-	27	PC												
	45	F	"	R	"	EX. B.	"	-	-	"		PC											
	49	M	"	R	"	"	"	-	-	26		C		C		CB		PC					
	"	"	"	L	"	ALC.	"	-	-	"	C				C								
6	50	M	2-	L	-	ALC.	1	-	-	23	N		CB	C				N	N	N			
	52	M	"	L	-	"	"	-	-	"	N				CB	C		N					
7	55	F	3-4	L	-	ALC.	3	-	-	30	PC												
	56	F	"	L	-	ALC.	"	+	-	"		C											
	57	F	"	R	-	$CACL_2$	1	+	-	21		CB	CB	CB	CB	CB	CB	C	C	C		C	
	"	"	"	L	-	ALC.	3	+	-	30				C	C	C						C	
	58	M	"	L	-	ALC.	"	+	-	"	PC	PC	PC	C		CB	CB						
8	63	M	3	L	-	ALC.	2	-	+	26		PC						M	M	N			
	66	F	"	"	-	"	"	-	+	26	PC							N					
	69	F	"	"	-	"	"	-	-	25	C	C										N	
9	72	M	1+	L	-	ALC.	1	+	-	28	M						C						
	74	F	"	"	-	"	"	+	+	"	M				C	C	CB	C					
	76	M	"	"	-	"	"	-	+	"	M	C						C	M				
	77	M	"	"	-	"	"	+	+	"	M		C	C		N	N	N					
	78	M	"	"	-	"	"	-	+	"	N	M					C	C					
	"	"	"	R	-	$CACL_2$	"	"	+	"	M	PC											
	81	M	"	L	-	ALC.	"	-	-	"						CB	CB	CB	CB				

PC = PRECARTILAGE. C = CARTILAGE. B = BONE. ▨ = GOOD LESION.
M = MILD LESION. N = NO LESION. □ = NOT SECTIONED.
EX. M. = EXTRACT OF MUSCLE. EX. B. = EXTRACT OF BONE. ALC. = 40% ALCOHOL. AC. ALC. = HCl - ALCOHOL.

Diethylstilbestrol, administered intramuscularly every other day in 2-milligram doses, did not influence the production of metaplastic cartilage and bone. Eleven of thirty-six animals so treated (31 per cent.) had positive results. In the control animals, thirteen of thirty-seven (35 per cent.) had positive results. The amount of cartilage or bone was the same in both groups.

In general, young animals tended to form larger and more widespread areas of meta-

FIG. 2-A

Experiment 9, Rabbit 81. Two nodules of chondro-osseous tissue are evident in the proximal portion of the left quadriceps. Intramuscular and subcutaneous calcifications are especially evident in the right limb. Roentgenogram taken twenty-eight days after the injection of 40 per cent. alcohol on the left and 1 per cent. calcium chloride on the right. The histological appearance of the two nodules is shown in Fig. 2-B.

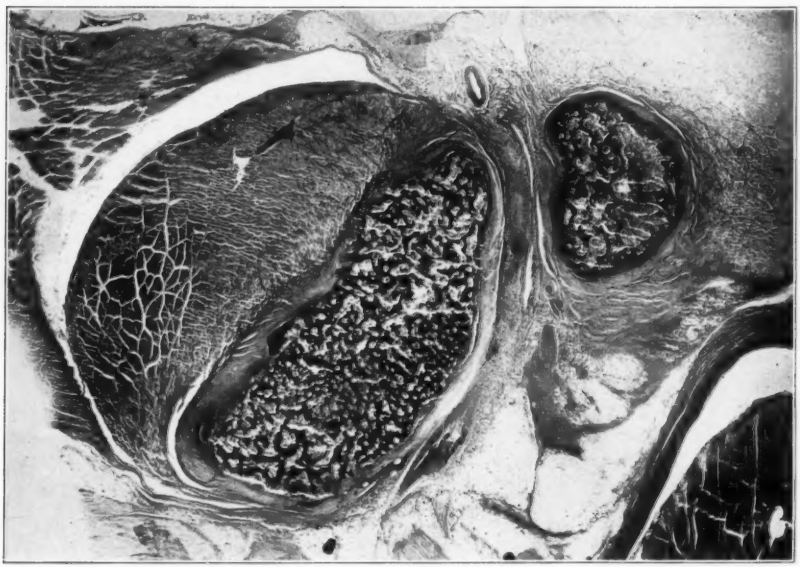

FIG. 2-B

Large nodule of chondro-osseous tissue (× 11) in the proximal end of the posterior portion of the rectus femoris, occurring twenty-eight days after one injection of 40 per cent. alcohol. The nodule lies adjacent to the dense fibrous septum which extends down the middle of this muscle. A smaller nodule is seen in the contiguous muscle. Frozen section, Wright's stain.

plastic cartilage and bone. In Experiments 6, 9, and 10, the animals were less than two months old, and were appreciably smaller than those in the other experiments. Of fifty muscles with adequate lesions, twenty-one gave positive results (42 per cent.). On the other hand, of 117 muscles in the older animals, thirty-five positive results (30 per cent.) were obtained.

TABLE 3

EXP. NO.	RABBIT NO.	SEX	AGE-MOS.	SIDE-R.L.	SUBSTANCE PRE-INJECTED	SUBSTANCE INJECTED	NO. INJECTIONS	EXERCISE	STILBESTROL	DURATION-DAYS	QUADRICEPS ← INSERTION ORIGIN → NUMBER OF MUSCLE-SLICE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
3	26	M	3-4	R	ALC.	EX.B.	3	-	-	29	C C
	27	F	"	R	"	"	"	-	-	"	PC
5	44	F	5+	R	"	"	"	-	-	27	C
6	50	M	2-	L	-	ALC.	1	-	-	23	PC C
7	55	F	3-4	L	-	ALC.	3	-	-	30	PC PC
	57	F	"	R	-	$CACL_2$	1	+	-	21	CB CB CB CB
	"	"	"	L	-	ALC.	3	+	-	30	PC CB C CB CB
	58	M	"	R	-	$CACL_2$	1	+	-	21	M CB CB
8	66	F	3	R	-	$CACL_2$	2	-	+	26	C
	68	M	"	L	-	ALC.	"	-	-	21	N C N
	69	F	"	L		"	"	-	-	25	N N PC C N
9	71	M	1	R	-	$CACL_2$	1	+	-	28	M C
	"	"	"	L	-	ALC.	"	+	-	"	CB PC
	72	M	"	L	-	"	"	+	-	"	C
	73	F	"	L	-	ALC.	"	-	-	"	PC PC M M N
	74	F	"	L	-	"	"	+	+	"	C PC M
	77	M	"	R	-	$CACL_2$	"	+	+	"	M M M M C M
	"	"	"	L	-	ALC.	"	+	+	"	C C CB CB N
	80	M	"	L	-	"	"	-	-	"	CB CB B M M
	81	M	"	L	-	"	"	-	-	"	C CB N
10	82	F	"	R	-	$CACL_2$	"	+	-	"	CB M
	84	M	"	R	-	$CACL_2$	"	+	-	"	CB CB B

PC = PRECARTILAGE. C = CARTILAGE. B = BONE. ▨ = GOOD LESION.
M = MILD LESION. N = NO LESION. □ = NOT SECTIONED.
EX.M. = EXTRACT OF MUSCLE. EX.B. = EXTRACT OF BONE. ALC. = 40% ALCOHOL. AC.ALC. = HCl-ALCOHOL.

Forced exercise of animals after injection of the irritant substances increased the incidence of bone and cartilage formation; also, the amount of chondro-osseous substance tended to be greater in the exercised animals. In Experiments 7, 9, and 10, some of the animals were exercised in a rotating cylindrical cage. Of thirty-nine adequately injected muscles in the exercised rabbits, eighteen (46 per cent.) gave positive results, as compared with eight of thirty-five (23 per cent.) for the non-exercised controls. From Tables II and III, the widespread incidence of cartilage and bone in the muscles of some of the exercised animals can be noted. In animal 57, which was exercised intensively, both triceps and quadriceps contained cartilage, either alone or in combination with bone, which was more widely distributed in multiple foci than was seen in any other experiment.

DISCUSSION

On the basis of the results of these experiments and those cited from the literature, the existence of a specific osteogenetic substance in alcoholic extracts of cartilage and bone has not been established. Cartilage or bone has been obtained by the injection of non-specific substances. Although Levander, Annersten, and Bertelsen obtained no bone or cartilage in animals injected with alcohol alone, Martin Lagos and Zarapico Romero obtained positive results in seven of eighty-seven rabbits (8 per cent.). Annersten obtained positive results in one animal injected with extract of tendon; in one, with extract of

muscle; and in two, with a calcium-phosphorus-alcohol mixture. Bone and cartilage occurred in one of Bertelsen's controls which had been injected with extract of liver. In the experiments reported here, cartilage and bone, alone or in combination, were produced in twenty-three of twenty-seven triceps (62 per cent.) and in twelve of forty quadriceps (30 per cent.) by the intramuscular injection of alcohol alone.*

The criteria for positive results have not been uniform among workers in this field. Many of the illustrations of Levander and Annersten show unmistakable mature cartilage and bone. Annersten presents an illustration (page 41), showing a transition stage between young connective tissue and early cartilage. For the calculation of positive results, he does not state at what stage in this transition he considered a tissue to be cartilage. Such a decision is often difficult. Bertelsen, who obtained cartilage or bone in twenty-nine of sixty injected muscles, states (page 165): "The changes, however, were as a rule limited to small islands or streaks in the excised tissues; they were sparse, but still very characteristic. Apart from one or two cases, however, the cartilage found was not 'mature', large-celled, but small-celled of foetal type with connective-tissue-like cells." In our sections, too, there appeared an intermediate tissue in which the matrix took a pale blue-green color with Wright's stain and was larger in amount than in typical fibrous tissue. This tissue was similar to early cartilage, and was often seen near areas of mature cartilage. However, since it was also observed often in these muscles without mature cartilage, it has not been considered "pre-cartilage" in evaluating results. Early capsules have been evident in the tissue we have classified as "pre-cartilage".

While the mechanism of this reaction is completely unknown, all workers agree that injury sufficient to cause proliferative repair is essential. Levander [13] obtained negative results in ten muscles injected with aqueous extracts of bone. Oily extracts, which caused little cellular proliferation, proved negative for Annersten. In our experiments, autogenous blood, which was resorbed with very little reaction, yielded negative results. Levander and Annersten emphasized the necessity of obtaining sufficient organizing connective tissue; and, in testing many of their extracts, they used a "pre-injection" of 40 per cent. alcohol to obtain this. Likewise, all agree that extensive necrosis, especially if accompanied by suppuration, is detrimental to the formation of ectopic bone and cartilage. Annersten has emphasized this point. In spite of extensive proliferation of connective tissue at the periphery of abscesses, bone and cartilage did not form in such regions in any of our animals.

It is self-evident that a minimal amount of time must elapse following the injury for bone or cartilage to appear. Although Annersten reported three positive results at eight, nine, and eleven days, by far the majority of his positive results were obtained in animals killed seventeen days or longer after injection. The sacrifice of his controls injected with alcohol alone, or with alcoholic extracts of autoclaved bone, ten days after injection (with negative results), may have allowed too short a time interval. Levander did not state the time intervals for any of his controls, all of which were negative.

Whereas the age of the animals is an important consideration in evaluating results, neither Annersten nor Levander stated the age or weight of the test rabbits used. Annersten did mention that the extracts were prepared from rabbits three to six months old.

We have observed cartilage remnants in all instances in which bone was found, and have never observed bone alone. Therefore, we believe that the primary tissue found in this intramuscular ossification is cartilage, with subsequent appearance of bone both by endochondral replacement and by intramembranous ossification. With alcohol alone or with calcium chloride, we have obtained intramuscular nodules of chondro-osseous tissue, which show as much organization as that which Lacroix [11,12] ascribed to his alcoholic extracts of epiphyses of younger rabbits (Fig. 2-B).

* Since this article was submitted, Hartley, Tanz, and Schneider have reported that bone occurred in three of eleven mature rabbits, fifty-three days after the injection into the thigh muscles of alcoholic extract of the ends of the long bones of young rabbits.

It is unfortunate that the search for the hypothetical substance has been confined largely to the rabbit *, since this species has manifested a high incidence of ectopic cartilage and bone in many organs, following a wide variety of experimental procedures. Severi obtained cartilage or bone in five of fifteen rabbits (33 per cent.), following repeated intramuscular injections of quinine hydrochloride. Cartilage or bone has been observed in the muscles of rabbits, following injections of calcium chloride [19], following traumatization [6, 7, 16], and following traumatization plus injections of bone autolysates [19]. After injection of formic acid into the vitreous body, Imai found bone in the eyes of twelve of twenty-six rabbits (46 per cent.). Engelstad observed that roentgen irradiation, sufficiently intense to cause degenerative pulmonary changes, was followed by bone formation in the lungs of fifteen of twenty-eight rabbits (53 per cent.). After application of silver nitrate or copper sulphate to the abdominal aortae of ten rabbits, Harvey obtained bone in five and osteoid tissue in three.

The claim of Blum that locally injected phosphatase leads to the formation of ectopic bone is open to question. His alginate gel-phosphatase mixtures contained a highly irritant concentration of calcium chloride. Since von Seemen stated that Goto had obtained ectopic bone in rabbits by the injection of calcium chloride, and since we have obtained bone or cartilage, or both, in two of twenty-seven triceps and seven of twenty-nine quadriceps with calcium chloride, it seems probable that this is the responsible ingredient in Blum's mixtures rather than the injected phosphatase.

SUMMARY

1. Following intramuscular injection into rabbits of alcohol alone, twenty-three of thirty-seven triceps (62 per cent.) and twelve of forty quadriceps (30 per cent.) contained cartilage or bone, alone or in combination.

2. Two of twenty-seven triceps and seven of twenty-nine quadriceps contained cartilage or bone, or both, following injection of calcium chloride.

3. There is a greater tendency for pre-cartilage, cartilage, and bone to form near the origin or the insertions of muscles than in the mid-portions.

4. Younger animals (one month old) formed larger amounts of more mature cartilage and bone than older rabbits, following injection of alcohol alone or of calcium chloride.

5. There was no appreciable difference in the frequency of bone and cartilage on the basis of sex.

6. Diethylstilbestrol, in the dosages used, did not influence the course of the intramuscular reactions.

7. The incidence and extent of intramuscular cartilage and bone was increased by exercising the animals.

8. Intramuscular cartilage and bone formation was not observed if suppuration occurred as a result of the injection of the irritant solutions.

CONCLUSIONS

1. In the rabbit, ectopic chondrification and ossification frequently follow intramuscular injection of irritating substances,—such as alcohol, calcium chloride, or mixtures which contain these irritants.

2. Intramuscular injection of extracts of bone, cartilage, or muscle does not produce cartilage or bone more frequently or more extensively than does the extracting fluid alone. The existence of a specific osteogenetic substance ("osteogenin") in extracts of skeletal tissue cannot be accepted as proved.

NOTE: The authors wish to thank Franklin C. McLean, M.D., and C. Howard Hatcher, M.D., for their advice and suggestions throughout the course of this investigation.

* Recently Pfeiffer has injected alcoholic osseous extracts into the testes of mice, but has obtained no cartilage or bone.

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THE GROWTH OF THE BONE MARROW *

BY PIERRE LACROIX, M.D., LOUVAIN, BELGIUM

From the Department of Anatomy, University of Louvain

Among the numerous papers on bone marrow listed in the *Index Medicus*, only that of Huggins and Smith is concerned with the question of how marrow grows, as compared with growth of the other parts of the bone. These authors stated that, following intravenous injection, thorium dioxide becomes firmly fixed in the bone marrow; in the young animal, subsequent areas of marrow growth are thorium-free, allowing recognition of the new tissue by roentgenographic and histological techniques. The conclusion is drawn that the bone marrow increases in length principally at the metaphyses, and grows in thickness at its circumference.

The author has repeated these experiments, and the results, while confirming in the main the conclusions of Huggins and Smith, include additional information which may be worth recording.

EXPERIMENTS

Ten six-week-old rabbits were injected intravenously with an electronegative thorium sol (thorotrast), containing approximately 25 per cent. of thorium dioxide. At two-day intervals, they received four injections totaling 10 cubic centimeters, or about 20 cubic centimeters per kilogram. No immediate ill effects were observed; it is well known that some months elapse before the toxicity from this substance develops.

On the day the injections were completed, the medullary cavity seemed blurred on the roentgenographic film. One of the animals was sacrificed and examined histologically. Scattered among the other cells, the histiocytes of the marrow were found to have accumulated particles of thorium. The growth of the other nine animals has been observed, and identical results have been noted in all.

Four days after the last injection (Fig. 1-A), a clear area began to appear in the marrow about the shadow of the thorium-laden portion of the tibia. This shadow had the same shape the medullary cavity had had a few days before. Thirty days later (Fig. 1-B), the clear zone had enlarged everywhere. The shadow had kept its transverse diameters, but had definitely increased in length.

It is difficult to decide, even with the aid of histological examination, whether this longitudinal growth is the result of intussusception all over the marrow or, as the presence of a central lacuna suggests, of the formation of new tissue at the place where the nutrient artery enters the marrow.

The same description applies to the other bones. In the radius and ulna (Figs. 2-A and 2-B) the inequality of growth between the fore legs and hind legs emphasizes the following observation: The clear zone between the end of the medullary shadow and the end of the medullary cavity enlarges, in each case, at a rate which is exactly proportional to the rate of growth of the neighboring epiphyseal cartilage.

DISCUSSION

The evidence given here can only concern the growth of the marrow, inasmuch as the thorium-laden cells may be assumed to remain in the same place from the beginning to the end of the experiment. Lambin has shown that the marrow attempts to get rid of the histiocytes which have accumulated particles of thorium; they slowly migrate, he says, toward the axial region of the marrow.

* Received for publication November 18, 1948.

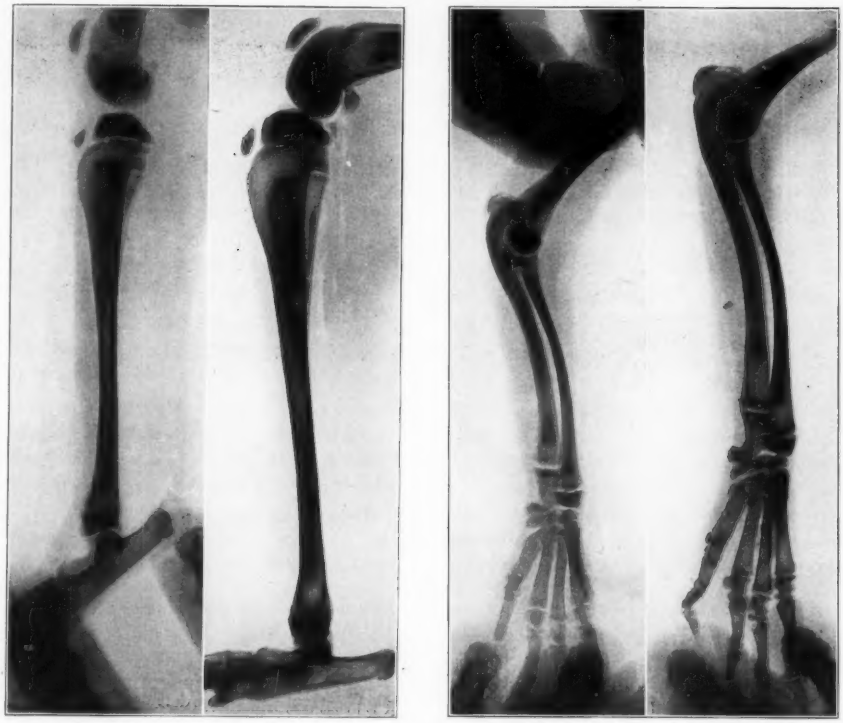

FIG. 1-A FIG. 1-B FIG. 2-A FIG. 2-B

Fig. 1-A: Roentgenogram of the tibia of a young rabbit, four days after completion of intravenous injections of thorotrast. A clear area has begun to appear about the thorium-laden portion of the marrow.

Fig. 1-B: Thirty days later, the clear area has enlarged and the medullary shadow is definitely longer.

Fig. 2-A: Same experiment. Roentgenograms of radius and ulna, four days after last injection.

Fig. 2-B: Thirty days later, the clear zone around the medullary shadow has enlarged and the shadow itself has increased in length.

We think, nevertheless, that the roentgenograms of Huggins and Smith, together with ours, may be considered as giving a true picture of the way marrow grows, provided only those roentgenograms are compared which have been taken at brief intervals. Our principal reason for this belief is that there is an accurate relationship between the rate of growth of a given epiphyseal cartilage, on the one hand, and the rate at which the same cartilage grows away from the medullary shadow, on the other hand. The alternative explanation would be to admit a migration of the histiocytes, different in rate and in direction in every case,—an explanation which must obviously be discarded.

We may conclude, therefore, that the bone marrow grows by a combined process of peripheral addition of new tissue and interstitial growth. (When speaking of interstitial growth, however, we must leave unanswered the question of whether we deal with uniform intussusception or with a kind of breaking up in fragments which have subsequently drifted apart.) The growth of the marrow thus appears as intermediate between the growth of the bone tissue, which is exclusively a peripheral effect, and that of the periosteum, which is interstitial[2].

Huggins and Smith emphasized the peripheral growth of the marrow, but neglected its interstitial growth. In the roentgenograms of the knee, illustrating their paper, neither the femur nor the tibia is shown in its entirety. It will appear from the present study that

a more complete picture of the phenomenon is gained by a comparison of bones which have been x-rayed in their entire length.

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EXPERIENCES IN THE USE OF HOMOGENOUS (BONE BANK) BONE *

BY JAMES B. WEAVER, M.D., KANSAS CITY, KANSAS

From the Orthopaedic Service, University of Kansas Medical Center, Kansas City

The use of homogenous bone grafts is not new; reports concerning these grafts have appeared in the literature from time to time. The impetus for the modern use of preserved homogenous grafts was probably given by Inclán's report, published in 1942, aided by the tremendous strides in the manufacture of "deep-freeze" equipment and in research concerning the freezing and storing of foods. At present many clinics, both in this country and abroad, are experimenting with homogenous grafts, usually preserved by freezing and storing in a so-called bone bank. Optimistic reports have already been made [1,2,4], but they give scant attention to the use of massive grafts, particularly in the repair of nonunion of fractures.

It is the purpose of this paper to present a report of forty-nine operations upon forty-six patients in whom homogenous bone, preserved in a frozen state, was used for grafting. This series includes all patients operated upon between July 1, 1946, and September 1, 1948, whose end result, as regards success or failure of the graft, is known.

SELECTION OF CASES

No attempt was made to select favorable cases. Frozen homogenous bone was used for all patients in need of bone-grafting, who presented themselves during the period of this study. Patients entering the Medical Center are, as a rule, referred because of previous failures and complications, or because of the severity of the condition and the generally unfavorable prognosis. Of the forty-six patients in this series, ten had had a total of sixteen previous bone-graft operations, all with autogenous bone and all failures. Twenty-three patients had each had from one to four operations, other than bone-grafting, at the site of subsequent surgery, and sixteen patients had had gross infection at the operative site. In evaluating the results, these figures should be borne in mind. The prime object of this study was to put the use of preserved homogenous grafts to a rigorous test, and it is felt that in this series of cases that purpose was achieved.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1949.

SURGICAL PROCEDURES

No attempt was made to follow a set pattern of operative procedure, but rather to try as many different types of grafts and techniques as the material at hand permitted. Thus, massive grafts were used as onlays, inlays, bone pegs, dual grafts, and in the Phemister type of graft, both with and without the addition of bone chips. The plentiful supply of donor bone permitted the trial of new procedures, such as arthrodesis of the shoulder joint in three cases, to be described. All patients received prophylactic doses of penicillin, usually over a postoperative period of seven to ten days. The two patients with tuberculosis received streptomycin.

Most of the surgery was done by the author or by members of his house staff. However, bone was used for a few cases on other services at the Medical Center, and several operations were done in other hospitals. In all, there were ten operating surgeons.

DONOR BONE

Procurement of Bone

Donor bone was secured from patients at operations in which bone was removed—that is, clean amputations, rib resections, et cetera—and from fresh cadavera. In all instances, the donors had had negative serological findings and were free from any known infectious disease, malignant lesion, or blood dyscrasia. Cadaver bone was secured only from young adults who had met a sudden traumatic death. Bone was removed from the cadaver within two hours after death and under as near operating-room technique as possible, the chief difference being that the surgery was done in the morgue rather than in an operating room.

Method of Processing Bone

The bone for storage was carefully denuded of soft tissue, the periosteum being left intact, if possible. In the case of cortical bone, portions were then fashioned with a motor saw and osteotome to the proper size for use as massive grafts. Carpal and tarsal bones, which were to be used as a source of cancellous bone, were stored as such. Femoral condyles are an excellent source of cancellous bone, and, when available, the condyles were sectioned into portions most likely to furnish enough bone for one operation. Ribs were stored singly and intact.

In the first year of this study, the sectioned bone was enclosed in sterile wrappers of cotton cloth and then in sterile oiled silk, and was appropriately labeled. Storage was in a deep-freeze unit in which the temperature was held to minus 40 degrees centigrade by the addition of dry ice.

During the second year, bone has been placed in sealed glass bottles, according to the method of Bush, frozen, and stored in an ice-cream-storage cabinet in which the temperature is kept between minus 20 and minus 25 degrees centigrade. There has been no noticeable difference in results between these two methods, but it is believed that Bush's method of bottling is superior, because one is able to view the bone and make more accurate selections as to the size and amount desired for a particular operation. No preservative chemicals, or bactericidal or antibiotic agents were used. Culture studies were not done. At the time of surgery, the donor bone was brought to the operating room and placed in sterile warm saline solution until used. Normal saline solution is believed to have no deleterious effect upon the bone graft.

In two instances, frozen bone has been shipped elsewhere, the procedure being the same as that used for shipping small quantities of ice cream. The bottle containing the bone is placed in a corrugated-cardboard ice-cream-shipping container and packed with dry ice. In both cases, more than twelve hours and less than twenty-four hours elapsed before the bone was again placed in a deep-freeze unit. The bone arrived at its destination in good condition. In one instance the operation was successful, after two previous failures with autogenous bone; the result is not yet known in the other case.

TABLE I

CONDITION	PART	NO.	SUCCESS	FAILURE	INFECTION
UNUNITED FRACTURES	TIBIA	9	6	3	2
	ULNA	5	3	2	0
	RADIUS	4	3	1	0
	FEMUR	4	3	1	0
	HUMERUS	2	2	0	0
	TOTAL	20	14.5 (72.5%)	5.5 (27.5%)	2 (10%)
BONE DEFECTS	TUMORS	9	9	0	0
	OSTEOMYELITIS	2	1	1	0
	TOTAL	11	10 (91%)	1 (9%)	0
ARTHRODESIS OF JOINTS	SPINE	6	6	0	0
	HIP	4	4	0	1
	SHOULDER	3	3	0	0
	ANKLE	1	1	0	0
	TOTAL	14	14 (100%)	0	1 (7.1%)
MISCELLANEOUS	BONE BLOCK	2	1	1	0
	OSTEOTOMY	2	1	1	1
	TOTAL	4	2 (50%)	2 (50%)	1 (25%)
GRAND TOTAL		49	40.5 (82.6%)	8.5 (17.3%)	4 (8.1%)

Indications for bone-grafting and results in forty-nine operations.

Length of Storage Time

The length of storage time before use has varied greatly. The shortest period was three days and the longest, 308 days (ten months); both cases were successful. In seven instances, the storage time was over six months; the average time for the entire series was 134 days (over four months). Length of storage time apparently has had no effect on the success or failure of the graft.

In the experimental laboratory, grafts applied to rabbits, in which the bone was used after eighteen months of storage, have been successful. No attempt has been made to use bone that has been stored a longer length of time.

STATISTICAL DATA

The forty-nine operations in this survey have been analyzed as to the indications for bone-grafting, the success, failure, or complication of infection being noted in each case. An operation for non-union at times involved two bones, such as the radius and ulna; hence the total number of bones operated upon is greater than the number of operations (Table I). For the same reason, fractions appear in the totals. In one operation, a graft of the radius and ulna was done with resultant union of the radius and non-union of the ulna. Thus, one-half unit was allowed for each success or failure.

Of the nine tumor cases, eight were either giant-cell tumor or solitary cyst, and one was metastatic carcinoma.

TABLE 2					
TYPE OF GRAFT	CONDITION	NO.	SUCCESS	FAILURE	INFECTION
MASSIVE	NON UNION	13	9.5	3.5	2
	BONE DEFECTS	2	1	1	0
	ARTHRODESIS	4	4	0	0
	MISCELLANEOUS	4	2	2	1
	TOTAL	23	16.5 (71.8%)	6.5 (28.2%)	3 (13%)
COMBINATION	NON UNION	7	5	2	0
	BONE DEFECTS	3	3	0	0
	ARTHRODESIS	5	5	0	0
	TOTAL	15	13 (86.7%)	2 (13.3%)	0
CHIP	BONE DEFECTS	6	6	0	0
	ARTHRODESIS	5	5	0	1
	TOTAL	11	11 (100%)	0	1 (9%)
GRAND TOTAL		49	40.5 (82.6%)	8.5 (17.3%)	4 (8.1%)

Type of graft employed and results.

The arthrodesing operations of the spine were performed for either scoliosis or spondylolisthesis. Fusion of the hip was done on one patient with tuberculosis; the other fusion operations were done for painful arthritis. In one case each of tuberculosis, flail joint, and chronic recurrent dislocation, fusion of the shoulder was done.

In the miscellaneous group, the two bone-block procedures were the Thompson operation to hold the thumb in abduction. The two osteotomies were for the correction of deformity of the tibia; in each case a rib was placed beneath the periosteum, on the posterior surface of the tibia.

TABLE 3					
DONORS	CONDITION	NO.	SUCCESS	FAILURE	INFECTION
FRESH CADAVER	NON UNION	9	7.5	1.5	1
	BONE DEFECTS	5	5	0	0
	ARTHRODESIS	3	3	0	1
	TOTAL	17	15.5 (91.2%)	1.5 (8.8%)	2 (11.7%)
PATIENTS	NON UNION	11	7	4	1
	BONE DEFECTS	6	5	1	0
	ARTHRODESIS	11	11	0	0
	MISCELLANEOUS	4	2	2	1
	TOTAL	32	25 (78.1%)	7 (21.9%)	2 (6.2%)
GRAND TOTAL		49	40.5 (82.6%)	8.5 (17.3%)	4 (8.1%)

Comparison between donor bone from patients and from fresh cadavera.

Highly satisfactory results were obtained after joint fusion (100 per cent. successful) and in the remedy of bone defects (91 per cent. successful). However, the successes in the treatment of non-union (72.5 per cent.) are not so good. In the entire group, there were 82.6 per cent. of successful results. The infection rate was 8.1 per cent., a high figure.

The same series of operations are presented in Table II, which shows the type of graft employed and the result as to success, failure, or infection. As previously stated, massive grafts were used in various ways. Combination grafts were those in which, in addition to a massive graft, either bone chips or "bone meal" were used with the express purpose of filling a bone defect. Bone meal was made by running cancellous bone chips or ribs through a coarse meat grinder. Chip grafts, as the name implies, were made up of cancellous bone obtained with the rongeur, curette, or bone cutters. Bone meal is included under the category of chip graft.

Although chip grafts appeared to be much more efficient, on the whole, they were used in cases with a more favorable prognosis.

Table III presents a comparative study of the efficiency of donor bone from patients and that from cadavera. The results indicate a higher percentage of success with the use of cadaver bone. This superiority is strengthened by the fact that more than 50 per cent. of the operations in which cadaver bone was used were for non-union of fractures, which are the most difficult cases. On the other hand, only 35 per cent. of the cases in which patient bone was used were in the non-union group. It is difficult to understand how cadaver bone could be more efficient, except that it offers a method of obtaining large quantities of the particular type of bone desired. The percentage of infection in the operations where cadaver bone was utilized is about twice that in the series where patient bone was used.

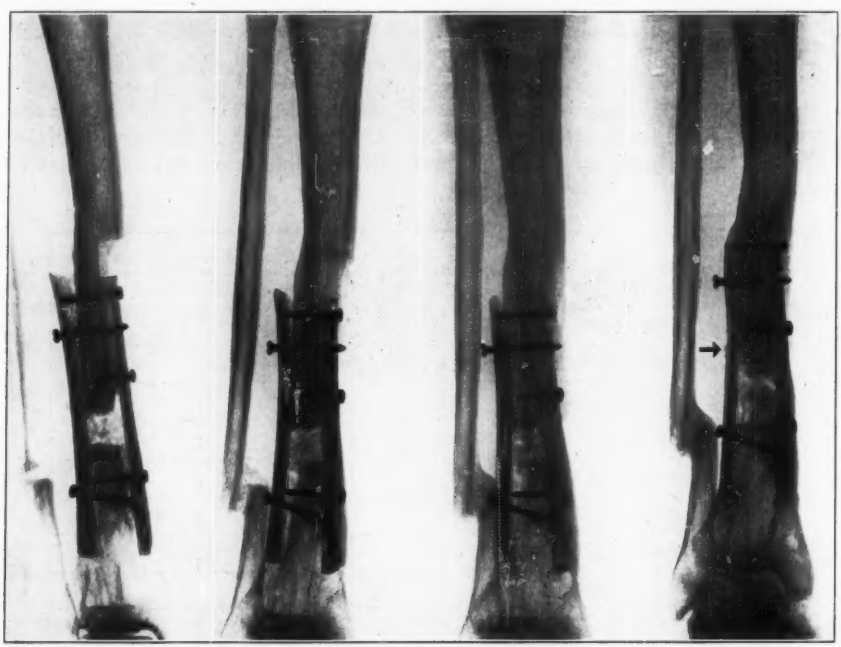

FIG. 1-A FIG. 1-B FIG. 1-C FIG. 1-D

Case 3-F. Roentgenograms show progressive healing of second graft at one-half month, two months, five months, and ten months. The view at ten months (Fig. 1-D) shows fracture of the graft.

CASE REPORTS

Failures

CASE 1-F. M.A., a woman, thirty-four years old, had sustained a compound fracture of the left femur, twenty-six months before admission. An open reduction was done with a metal-plate fixation; non-union occurred. The plate was removed, with resultant infection. A suitable time after drainage had ceased (and about a year before admission), an autogenous onlay bone graft had been applied. This resulted in failure. On June 17, 1947, a dual graft was applied, fibular bone being used for massive grafts and tarsal bone for cancellous bone chips. The femur was dense and sclerotic at the fracture site. An attempt was made to preserve length by filling the gap between the bone ends with bone chips. In the early months after surgery, roentgenograms were encouraging, but absorption of the graft at the fracture site finally occurred. At a later operation, residual grafts were removed; by microscopic examination they were considered dead bone, in the nature of a sequestra.

This was an unfavorable case and the technique was faulty. It would have been better to have accepted shortening of the extremity.

CASE 2-F. D. S., a thirteen-year-old boy, fractured both bones of the right forearm. After several attempts at closed reduction had failed, an open reduction was done and the fragments were wired together. Non-union resulted. A homogenous rib graft was applied on May 20, 1947. The use of rib in this instance, without additional internal fixation, was an error in judgment. There was a good deal of tension on the graft at the fracture site; the screws pulled through the graft; and displacement of the fragment with subsequent non-union occurred. A second attempt at bone-grafting was made on February 24, 1948, with homogenous fibula from a fresh cadaver. A satisfactory graft was affixed to the radius, but absorption had taken place in the ulna and it was impossible to affix a suitable graft with screws. A dual graft was, therefore, applied, and was held in place with chromic catgut. The graft of the radius became sclerotic, but bone bridged across the fracture site and union took place. Union did not occur in the ulna.

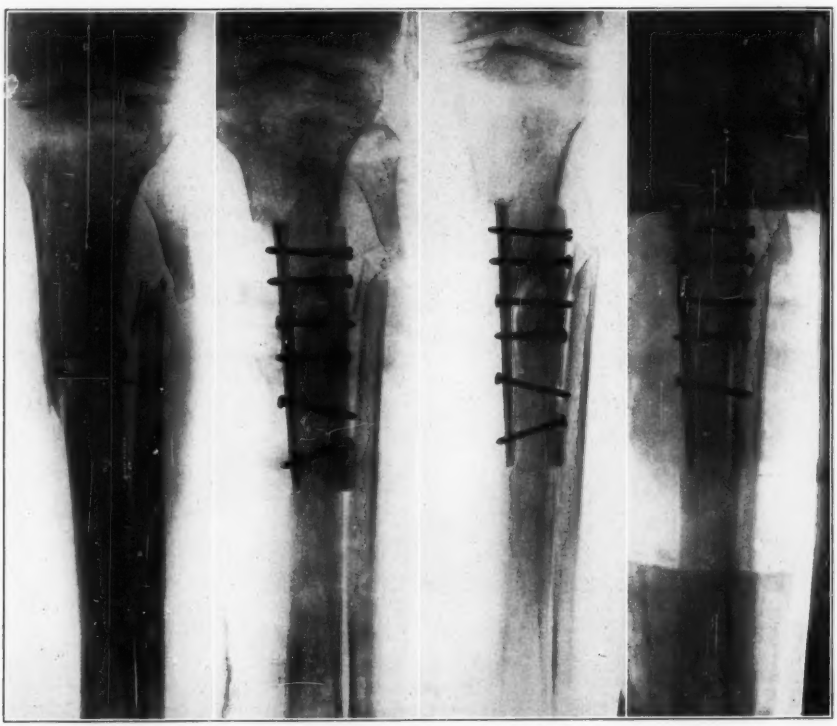

FIG. 2-A FIG. 2-B FIG. 2-C FIG. 2-D

Fig. 2-A: Case 5-F. Showing non-union of tibia.
Fig. 2-B: One week after application of dual graft.
Figs. 2-C and 2-D: Four months and seven months, respectively, after operation. Progressive destruction of the tibia from osteomyelitis may be noted.

CASE 3-F. W. B., a man, thirty-five years old, sustained compound fractures of the right tibia and fibula. He was treated with Stader splints; non-union resulted. After fourteen months a sliding bone graft was inserted, also resulting in failure. He was admitted to the Medical Center, where, on May 13, 1947, a homogenous bone graft was applied. Dual massive grafts of the ulna were used, with chips from carpal bones to fill the space between the bone ends. This patient's cast was changed two weeks after the operation; at that time the wound was clean, the stitches were removed, and he was dismissed from the Hospital. He failed to report for after-care until several months later. At that time he stated that, the week after leaving the Hospital or three weeks after the operation, he had removed his own cast, put on an old brace, started full weight-bearing, and gone to work as a filling-station attendant. Of course, non-union resulted.

A second operation was done on February 25, 1948. Dual onlay grafts of tibia from a fresh cadaver were used with cancellous bone chips from tarsal bones. The patient's cooperation was somewhat better this time. After seven months, the cast was replaced by a brace, but weight-bearing was not permitted (Figs. 1-A, 1-B, and 1-C). However, the patient began full weight-bearing without his brace. A month later, while carrying a trunk up a flight of stairs, he stumbled and fractured his tibia through the site of the graft (Fig. 1-D). A cast was applied, but he again failed to report for observation and it is understood that he entered a Veterans Hospital.

Failure of the first attempt was due to lack of cooperation on the part of the patient, but the operation is listed as a failure. The second attempt is considered a success. Progressive union and filling in of the bone defect were taking place until destroyed by this patient's carelessness.

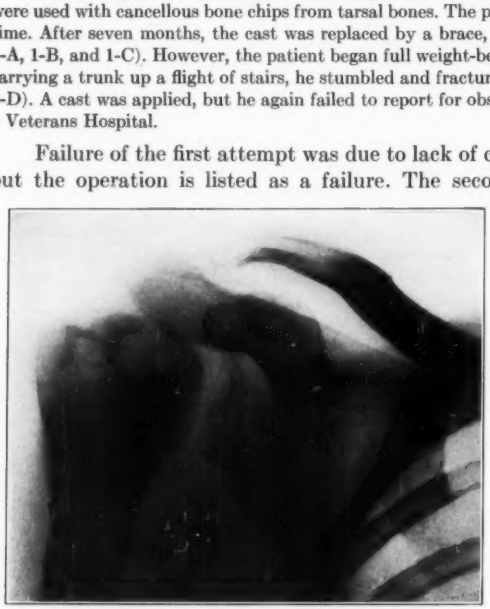

FIG. 3-A

Case 1-S. Preoperative roentgenogram showing tuberculosis of the shoulder joint.

CASE 4-F. E. D., a man, fifty-five years old, suffered compound fractures of both tibiae on August 6, 1947. Immediate amputation of the left leg was necessary. The wound of the right leg became grossly infected. After a period of time, drainage ceased and the wound healed, although no union took place at the fracture site. On June 3, 1948, a dual graft was applied and infection again ensued. A small area of tissue loss appeared over the tibia; the infection seemed to be mild in character. An attempt was made to cover the denuded area with a skin flap, but this was also a failure. The grafts became sequestrated and there was obvious osteomyelitis of the tibia.

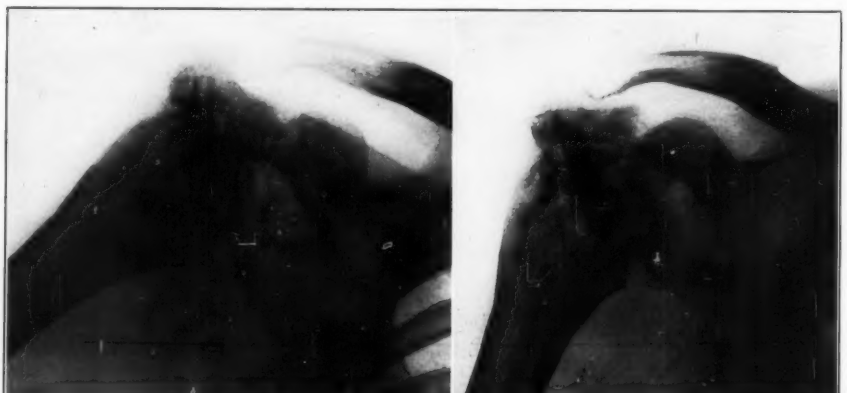

FIG. 3-B FIG. 3-C

One month and five months after surgery, there is clinical and roentgenographic evidence of fusion.

CASE 5-F. R. J., a man, fifty-eight years old, suffered a simple fracture of the left tibia on October 5, 1947. Open reduction was done and the oblique fracture was fixed with two long screws. Non-union resulted (Fig. 2-A), but at no time following the open reduction did this patient show any evidence of infection. On February 26, 1948, a dual graft was applied, tibial bone from a fresh cadaver being used. After removal of the bone screw, a single drop of pus was exuded. A culture was taken, which was later reported as positive for *Staphylococcus aureus*. A mild infection followed, consisting chiefly of tissue loss over the tibia. An attempt was made to cover the area with skin flaps, but this was unsuccessful. Sequestration of the graft and osteomyelitis were the result (Figs. 2-C and 2-D).

FIG. 4

Ten months after surgical fusion of a shoulder. Metatarsal bone was used as the bone peg.

CASE 6-F. A. S., a seventeen-year-old girl, had had a large cyst removed from the mandible; osteomyelitis ensued. Three bone grafts had been done, prior to admission. On May 6, 1948, a rib was used in an attempt to fashion an alveolar ridge, so that a prosthesis might be fitted. This graft was absorbed, although no infection was present.

This was a most unfavorable case, as little bone remained in which to fasten a graft.

CASE 7-F. J. K., an eighteen-year-old boy, was admitted with a malunited fracture of the tibia. An osteotomy was done on May 20, 1948, for correction of the deformity. A metal bone plate was applied to hold the tibia in correct position, and a rib was slipped beneath the periosteum, on the posterior surface. The postoperative course was uneventful. At eight weeks, when the cast was changed, ulceration was found in the wound over the tibia. There was mild drainage for several weeks, and the skin healed. Roentgenograms showed bone loss in the rib graft, which was evidently the site of infection. Non-union resulted.

CASE 8-F. W. P., a ten-year-old boy, had an adduction deformity of the thumb, due to cerebral palsy. A Thompson bone-block operation was done on May 20, 1948, a metacarpal bone being used between the first and second metacarpals. One end of the graft was absorbed, and displacement followed. There was no infection.

It is believed that faulty technique was largely responsible for this failure.

Selected Successful Cases

CASE 1-S. C. K., a negro man, twenty-eight years old, had arrested pulmonary tuberculosis, and active tuberculosis of one kidney and the left shoulder. First a nephrectomy was done and then, on April 20, 1948, an arthrodesis of the right shoulder. The shoulder condition had been rapidly progressive and, at the time of operation, there was a large abscess of the shoulder with a draining sinus low on the brachium (Fig. 3-A). After the joint had been opened, it was found that the head of the humerus, very necrotic, was floating in about 180 cubic centimeters of pus, contained in a markedly enlarged capsule. The head of the humerus was debrided as well as possible; the glenoid cavity was freshened; and all soft tissue was removed from the subacromial area. The inferior surface of the acromion was denuded to bleeding bone. The head of the humerus was pushed firmly against the glenoid and acromion process and the arm was held in the desired position, while a drill hole was placed through the acromion process and into the head. This was enlarged to accommodate a rib, which was then driven through the acromion process, into the head. Bone chips, fashioned from ribs, were placed in the dead space between the head of the humerus and the scapula. Five months after the operation, there was clinical fusion and no drainage. Roentgenograms (Fig. 3-C) showed excellent amalgamation of the component bone elements.

This technique has been used in two other shoulder operations with satisfactory results. Figure 4 shows one of them, ten months after operation.

CASE 2-S. V. B., a woman, thirty-nine years old, had arrested pulmonary tuberculosis and active tuberculosis of the left hip (Fig. 5-A). An arthrodesis of the hip was done on March 2, 1948. The greater trochanter was turned back and the superior margin of the acetabulum was turned up to form bone flaps. The superior surface of the neck of the femur was freshened. An iliac graft from a fresh cadaver was laid on

FIG. 5-A FIG. 5-B FIG. 5-C FIG. 5-D

Fig. 5-A: Case 2-S. Preoperative view shows tuberculosis of the left hip.
Fig. 5-B: Two months after surgical fusion.
Roentgenograms taken four months and six months after operation show progressive fusion to completion.

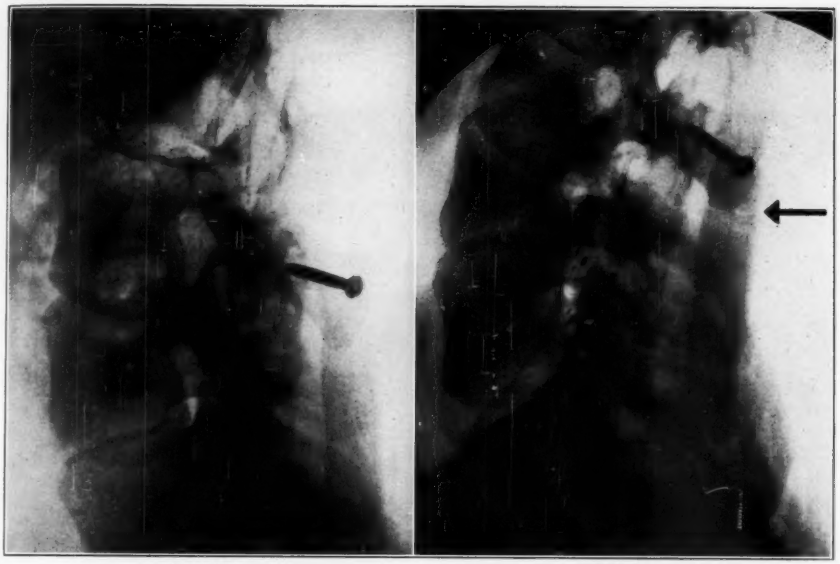

FIG. 6-A FIG. 6-B

Fig. 6-A: Case 3-S. Showing a massive graft of the lumbar spine, two and one-half months after operation.

Fig. 6-B: A fracture of the graft, just below spinous process to which the screw is affixed, occurred three and one-half months following surgery.

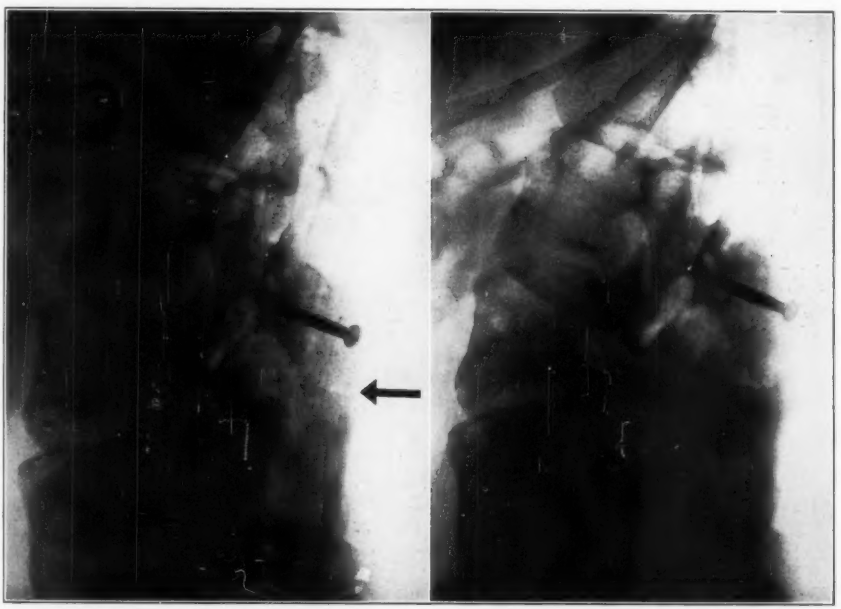

FIG. 6-C FIG. 6-D

Fig. 6-C: Five and one-half months after surgery and two months following the fracture, a good cloak of callus surrounds the fracture site.

Fig. 6-D: At eighteen months, there is marked hypertrophy of the graft.

FIG. 7-A

FIG. 7-B

FIG. 7-C

Fig. 7-A: Case 4-S. Shows ununited fracture of the femur at time of admission.

Figs. 7-B and 7-C: Six months and fourteen months after dual grafts had been applied. Solid union has occurred, both clinically and by roentgenographic examination.

Fig. 7-D: Ununited fractures of tibia at time of admission.

Figs. 7-E, 7-F, and 7-G: Two, four, and fourteen months after application of massive onlay grafts, roentgenograms show progressive union. Weight-bearing has not yet been permitted.

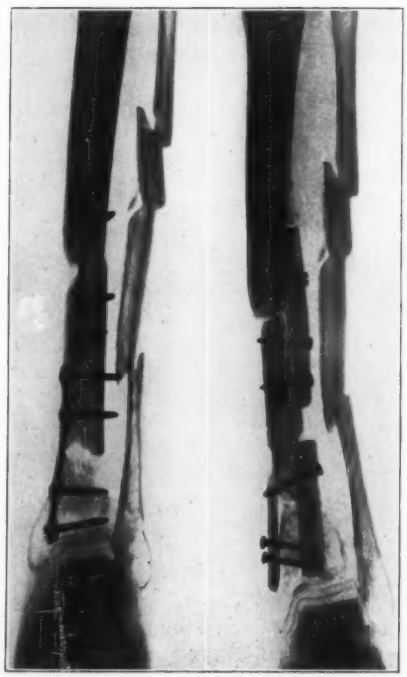

FIG. 7-D

FIG. 7-E

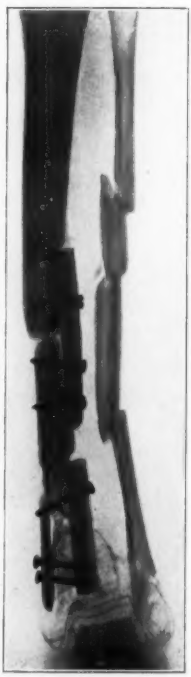

FIG. 7-F

FIG. 7-G

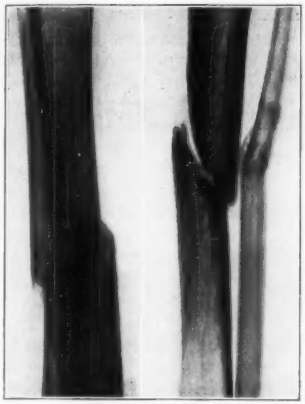

FIG. 8-A

Fig. 8-A: Case 5-S. Non-union of fracture of tibia at the time of admission.

Figs. 8-B, 8-C, and 8-D: Roentgenograms, taken at four, eight, and ten months after surgery, show progressive healing to complete union.

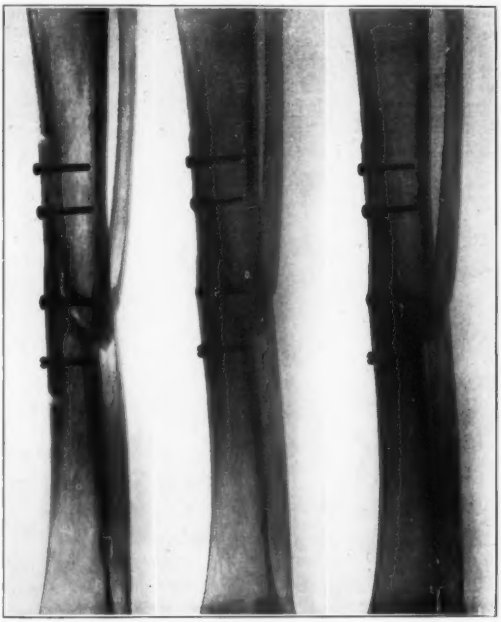

FIG. 8-B FIG. 8-C FIG. 8-D

the neck of the femur, under the bone flaps, and was held in place by a screw through the greater trochanter and graft (Fig. 5-B). There were no postoperative complications, and excellent fusion followed (Figs. 5-C and 5-D).

CASE 3-S. In G. P., a man of twenty-five years, a spine fusion was done on December 31, 1945, for paralytic scoliosis. The spinous processes of the lumbar vertebrae were denuded to raw bone on one side and a gutter was made in the laminae at their base. A long piece of split fibula fitted nicely into this bed and was easily held by a single screw, passed through the graft and a spinous process. Three months after operation, fusion appeared satisfactory and the patient became ambulatory, wearing a spine brace (Fig. 6-A). At three and one-half months, the patient was wrestling with a nephew and fractured the graft (Fig. 6-B). Six weeks later, roentgenograms showed callus about the fracture site, and the fractured graft progressed to complete union (Figs. 6-C and 6-D).

On December 30, 1947, the lower portion of the spine was fused. Ribs were used as grafts in this instance, placed between split spinous processes and in a gutter at one side. During the course of the operation, a portion of the fibular graft was removed; the pathologist's diagnosis was normal bone. Satisfactory fusion was obtained in both instances, and marked hypertrophy of the first graft had occurred.

CASE 4-S. H. T., a man, forty-two years old, sustained a simple fracture of the lower third of the left femur, and two fractures of the left tibia, one at the junction of the upper and middle thirds, and the other in the lower third. All three fractures were treated by open reduction. The femur was wired (Fig. 7-A), and plates were placed on the fractures of the tibia. The sites of the tibial fractures became infected. When this patient was first seen, eleven months after the accident, there was non-union of all three fractures and draining sinuses over the lower portion of the tibia. A dual graft of femur from a fresh cadaver was placed on the fractured femur and, at the same time, the plates were removed from the tibia. The surgical wound of the femur healed promptly, and soon thereafter the incisions over the tibia healed. Two months later, massive tibial grafts from a fresh cadaver were placed over the fracture sites in the tibia. Cancellous bone chips (femoral condyles from a fresh cadaver) were packed about these. At the time of operation, there had been little hope of union, as the central portion of the patient's tibia was practically a sequestrum, and the lower end of the tibia was so atrophic that a hemostat could easily be pushed through the bone. Union of the femur occurred, both clinically and by roentgenographic examination (Figs. 7-B and 7-C). Clinically, the fracture sites in the tibia felt firm, and roentgenograms over a fourteen-month period showed progressive union (Figs. 7-E, 7-F, and 7-G).

The bone bank filled a real need in this case of multiple non-union.

FIG. 9-A

Case 6-S. Lateral and anteroposterior views of osteomyelitic tibia at the time of admission.

CASE 5-S. R. H., an eighteen-year-old boy, fractured his left tibia and fibula on May 5, 1947, resulting in non-union (Fig. 8-A). On April 27, 1948, an onlay bone graft was applied, the femur from a cadaver being used. An excellent result was obtained (Figs. 8-B, 8-C, and 8-D).

CASE 6-S. C.S., a male, twenty-one years old, contracted hematogenous osteomyelitis of the tibia about four years before admission. He had had four operations with no relief. When first seen, he had a large fungating mass over the lower anterior portion of the tibia, with considerable drainage (Fig. 9-A). On September 3, 1946, the fungating mass was excised and all necrotic bone was curetted from the tibia. Posterolateral, longitudinal skin incisions were made; the skin was pulled together over the tibial defect and sutured. The wound healed promptly and no further drainage occurred (Fig. 9-B). On October 22, 1946, an incision was made through good skin, and the tibia was exposed at the site of the defect. A large tibial onlay graft was placed over the open side of the cavity, which was packed with cancellous chips from tarsal bones.

Follow-up roentgenograms showed progressive union (Figs. 9-C and 9-D). For over eighteen months, this patient has walked without apparatus and has been doing heavy farm work (Figs. 9-E and 9-F).

NOTE: In Cases 4-F and 7-F, reported as failures, union has occurred since this paper was presented.

DISCUSSION

From the experiences reported here, it seems obvious that homogenous bone, preserved by freezing, has not only limitations but also dangers. When used in the form of chip grafts in arthrodesing operations or in certain types of bone defects, excellent results may be expected. However, massive grafts are not so successful in cases of non-union. The same statements are applicable to autogenous grafts.

As regards amalgamation with recipient bone, there is certainly no reason to assume that the homogenous graft has inherent qualities which would make it superior. It may be just as good as autogenous bone, but not better. The only way in which the homogenous graft might lend itself to better results is that the surgeon may have as much bone of a particular type as he may desire. The results in this series, as they concern massive homogenous grafts for the repair of non-union of fractures, are not so good as the author's experience with autogenous grafts. However, the cases in this report have been, for the most part, difficult ones, and in several instances the homogenous graft has been called upon to do more than one would expect of an autogenous graft. It is felt that there is a greater tendency for the massive homogenous graft to "die" and, on the whole, the time of amalgamation has been longer.

This last statement is an impression, without definite data to prove it. In some cases, however, massive homogenous grafts have amalgamated as promptly as would be expected of an autogenous graft.

Many other factors are involved in the success or failure of any bone-graft procedure. The mechanics of the operation are most important and, in several instances of failure in this series, undoubtedly played an important part. In addition, there must be considered the condition of the recipient bone, the general condition of the patient, the cooperation of the patient, and many related factors.

It is fallacy to assume that the danger of infection is less with homogenous bone than

FIG. 9-F

FIG. 9-E

Lateral and anteroposterior roentgenograms taken eleven months and two years, respectively, after bone-grafting.

FIG. 9-D

FIG. 9-C

FIG. 9-B

Fig. 9-B: After removal of affected bone.
Figs. 9-C and 9-D: One and one-half and four months after application of graft.

with autogenous. Homogenous bone must be handled more than the autogenous bone, thus creating a greater hazard. However, this danger is offset by the fact that the patient does not have to undergo a second incision for the removal of bone, with its attendant possibilities of infection and fracture. This series presents a high percentage of infection, but in only one instance did infection occur in a truly clean field (Case 7-F). Roentgenograms of this case indicate that the rib graft was the seat of the infection. Another rib from the same donor was used in Case 6-F. It became absorbed rapidly, but there was no drainage. In all other cases where infection ensued, there was infection of the site, either past or present, and it would be difficult and unfair to place the blame entirely on the graft material. No attempt was made to sterilize the bone-graft material in this series. Such procedures are now under trial, and they may prove of value.

It is felt that bone from fresh cadavera is just as efficient as that taken from patients. Since it is generally believed that iliac bone is more efficient as regards osteogenetic properties, and since the cadaver offers an ample supply, the author has in recent months used iliac bone from fresh cadavera almost to the exclusion of other types.

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CLINICAL EVALUATION OF THE MERTHIOLATE BONE BANK

A Preliminary Report *

BY FRED C. REYNOLDS, M.D., AND DAVID R. OLIVER, M.D., ST. LOUIS, MISSOURI

From the Department of Surgery, Washington University School of Medicine, St. Louis

To justify the use of homogenous bone grafts, a clear understanding of the fate of transplanted bone, both autogenous and homogenous, is necessary. The consensus is that autogenous bone grafts are superior to homogenous grafts, because of the supposition that some elements of the transplants survive and retain their osteogenetic properties [1,3,8-10,14]. However, there are those who maintain that all elements of a bone transplant die and are replaced by the host tissue, regardless of the source of bone [2,11,16]. If the claims of the latter group are correct, there should be but minor differences in the process of fixation and replacement of autogenous and homogenous bone grafts.

In the past year, the authors [16] have made an experimental comparison of the fate of autogenous and homogenous bone grafts in dogs. The observations are in complete agree-

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1949.

ment with those of Barth, in that no evidence was found that any elements of autogenous bone transplants live and have reproductive powers.

The process of fixation and replacement of both autogenous and known dead homogenous bone is identical. It is accomplished by appositional new-bone growth from the host tissues in both instances. However, the early phases of healing occur at a slightly more rapid rate with the autogenous than with the homogenous grafts. The exact significance of the observation is unknown to us, but the explanation is probably related to the unknown factors of tissue specificity and host reaction, rather than to any persistence of life in the autogenous grafts.

The transplantation of homogenous bone is not a new procedure. Its use in the fresh state was first reported by Macewen in 1880, and by many workers thereafter. More recently, attempts have been made to preserve bone in various states as reported by Orell. Several French surgeons are said to have used frozen preserved bone [6]. Inclán, in 1942, demonstrated the successful use of frozen autogenous and homogenous bone. Bush has popularized the use of frozen homogenous bone as a "bone bank".

Morgan, Jamieson, and Powell reported the use of merthiolate solution as a preservative for biological products. O'Connor, in 1939, and Brown and DeMere have described the successful use of cartilage preserved in merthiolate. The simplicity and safety of this method of preservation of tissue aroused the authors' interest in the possibility of its application to the preservation of bone. Therefore, experimental studies were made, comparing the process of healing of merthiolate-preserved homogenous grafts with frozen and boiled homogenous grafts, as well as with autogenous grafts. From these studies, the authors concluded that the fixation and replacement of the merthiolate-preserved homogenous bone was essentially the same as that of the fresh autogenous grafts. Experimentally, bone preserved by freezing or by aqueous merthiolate was indistinguishable. Boiled homogenous grafts healed by the same process, but the healing was definitely delayed. From these experiments the clinical use of merthiolate-preserved bone seemed justifiable.

The procedure adopted for the establishment of a "merthiolate bone bank" is as follows: The bone is obtained from three sources: (1) ribs removed under aseptic conditions at thoracotomies and thoracoplasties; (2) bones obtained from amputations of uninfected parts; and (3) cancellous and cortical bone obtained at selected autopsies under as sterile conditions as possible. In preparing for storage the bone removed from these sources, sterile equipment and operating-room technique are employed. The periosteum and attached soft tissues are carefully removed from the bone, which is then split and cut into convenient lengths. A culture of the marrow contents is taken.

The bone is then put into sterile jars, containing a 1 to 1,000 solution of clear aqueous merthiolate. It is important that all bone be completely covered by the solution. At the end of two weeks, the bone is removed under operating-room technique, all remaining soft tissues are cleaned off, and it is placed in sterile jars containing a 1 to 5,000 solution of aqueous merthiolate. Another culture is taken at that time. The bone is kept in the 1 to 5,000 solution thereafter, being changed at two-week intervals and cultures being made. No grafts are removed from the bank for clinical use until at least two negative cultures have been obtained. To date, the authors have not encountered a single positive culture.

The container of preserved bone can be kept either in the operating room at room temperature or in a nearby household refrigerator. When a graft is needed, the container is opened in the operating room and the desired piece of bone is removed by the surgeon with sterile forceps. After being rinsed in normal saline solution, the graft is ready for use.

At the present time, merthiolate-preserved homogenous bone has been used in seventy-one patients. This report, however, presents the findings in the first forty-two consecutive cases in which merthiolate-preserved homogenous bone was used. The types of operative procedures and the general results obtained from each are shown in Table I.

TABLE I

RESULTS IN FORTY-TWO PATIENTS

Operation	No. of Patients	No. of Failures
Arthrodesis of major joints	5	0
Non-union	9	3
Spine fusion	15	2
Obliteration of osteomyelitic cavities	5	2
Obliteration of tumor cavities	3	0
Osteotomy defects	2	0
Open reductions	2	0
Aseptic necrosis of femoral head	1	0
Totals	42	7

Of nine operations on patients with non-union, three are considered failures at this time. Two of these failures occurred in fractures of the ulnar shaft; the other involved an old compound fracture of the lower portion of the humerus. Ribs were used as grafts in each instance. This type of graft does not lend itself to firm internal fixation, and is generally considered to be inferior to compact cortical bone for use in these locations. It may be that this factor has contributed to these failures. However, in two other cases of non-union of the ulnar shaft, treated in an identical manner, satisfactory union occurred. One of the patients with failure of union after an ulnar fracture had a recurrence of infection following the grafting procedure, which necessitated sequestrectomy at a later date. Figures 1-A, 1-B, and 2 illustrate the results obtained in cases of non-union.

Bank bone was used to obliterate the defects remaining after saucerization for osteomyelitis in five patients, each of whom had a draining sinus. One of these sites healed *per primam* and has remained healed; in four, drainage continued after operation. The drainage in two of them, however, subsided promptly without further surgery; the sinuses have remained healed and the patients have been free of symptoms. The other two patients, whose operations must be considered failures, require some explanation.

A. I., a doctor, had had osteomyelitis of the upper portion of the tibia with extensive bone defects and soft-tissue defects for nine years. Saucerization, grafting with bank bone, and the swinging of a large pedicle flap were performed in one stage. This overambitious surgery resulted in failure, with infection and necrosis of the skin flap.

K. B. had had non-union of the upper portion of the femur with infection for eight years. Three previous attempts at autogenous bone-grafting, performed elsewhere, had failed. A large osteomyelitic defect was present, together with extensive soft-tissue scarring. Following sequestrectomy and bridging of the defect by rib grafts, the wound was closed. However, the infection persisted, and drainage and non-union were present when the patient was last examined.

Figures 3-A, 3-B, 4-A, and 4-B show successful results obtained in patients of this group.

Spine fusions in this series were of the modified Hibbs type, reinforced by large amounts of merthiolate-preserved bone. Of the fifteen patients in this group, ten had fusions which appear to be definitely solid. In two patients, the final result is not yet known; one died before the graft was solid. A pseudarthrosis developed in one patient, and refusion was required. This we believe to have been caused by a fracture of the graft, as it followed an injury in which the patient heard a sharp snap, accompanied by pain. At operation, all the bone was solid, except at the line of pseudarthrosis. The other patient has only recently presented evidence of pseudarthrosis; reoperation has not yet been done.

Arthrodesis of major joints, including the hip, knee, ankle, wrist, and subtalar joint, was performed successfully in five patients. Intra-articular fusion, reinforced with bank bone, was done in all instances. No failures were encountered in this group.

FIG. 1-A

FIG. 1-B

C. E., a white male, aged forty-four, had non-union of the shaft of the ulna, following a Monteggia fracture, five months previously. An attempt at internal fixation had been made elsewhere.

Fig. 1-A: Roentgenograms taken at the time of admission.

Fig. 1-B: Appearance nine months after resection of head of radius and dual onlay graft. Ribs from the merthiolate bone bank were used for grafting. Excellent function was regained.

FIG. 2

J. K., a white male, aged forty-eight, had non-union of the shaft of the femur of eleven months' duration. The original treatment was open reduction and plate fixation. At the time of admission, the plate had broken and there was non-union. Two plates and merthiolate rib grafts were then applied. Four months after the second operation, definite union was evident grossly.

The process of replacement of the merthiolate graft by appositional growth of the host bone was identical, microscopically, to that seen in experimental animals.

In the remaining cases (Table I), the wounds healed by first intention, and all grafts appear to be fusing in a satisfactory manner. Bank bone was employed to obliterate the defect in three instances of benign bone tumor. In each case the postoperative course was uneventful and the grafts healed satisfactorily (Figs. 5-A and 5-B).

FIG. 3-A

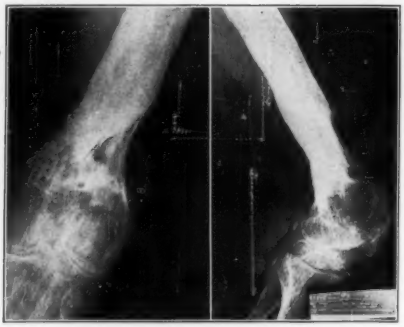

FIG. 3-B

G. A., a white male, thirty-eight years old, had chronic osteomyelitis of the left femur of twenty-three years' duration. Copious drainage was seen at the time of admission. A saucerization and sequestrectomy were done.

Fig. 3-A: After two weeks, the defect was filled with merthiolate rib grafts and the wound was closed. These roentgenograms show the femur after saucerization and before grafting.

Fig. 3-B: Roentgenographic appearance twelve months after operation. The patient has had no drainage since one month after operation and has been symptom-free.

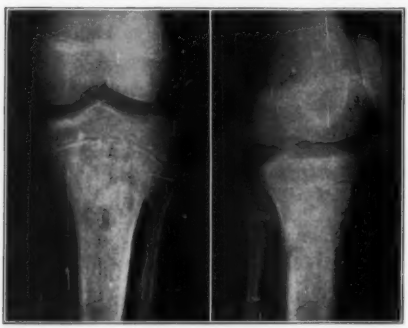

FIG. 4-A

FIG. 4-B

M. B., a white girl, aged twelve, had chronic osteomyelitis of the proximal portion of the right tibia of six months' duration. The focus was draining at the time of admission.

Fig. 4-A: Preoperative roentgenograms. Saucerization, sequestrectomy, filling of the defect with merthiolate rib grafts, and wound closure were done in one stage. The wound closed *per primam*, and the patient has had no drainage or symptoms since operation.

Fig. 4-B: Roentgenograms taken three months after operation.

Osteotomy defects were filled in two patients and solid union resulted. It seemed advisable to employ a bone graft as an aid in internal fixation in two instances. One was a subcapital fracture of the hip, in which grafting augmented a Smith-Petersen nail. In the other case, a merthiolate bone graft was used to fill a defect in the calcaneus, which had remained after elevation of a depressed fracture.

CONCLUSIONS

1. The process of fixation and replacement of both autogenous and known dead homogenous bone grafts is accomplished in an identical manner, experimentally and clinically.

2. The merthiolate bone bank offers a simple, inexpensive, and aseptic method of preserving homogenous bone.

3. Merthiolate-preserved bone is well tolerated in the tissues, and early results obtained with grafts from the merthiolate bone bank compare favorably with autogenous grafts under similar circumstances.

FIG. 5-A

FIG. 5-B

D. B., a white male, aged fourteen, had a central chondroma of the distal portion of the femur of eight months' duration, causing partial epiphyseal growth arrest on the lateral aspect.
Fig. 5-A: Roentgenograms taken at the time of admission. The tumor was excised locally and the defect was filled with merthiolate ribs and iliac-bone chips.
Fig. 5-B: Appearance of defect two months after operation.

4. No sensitivity to merthiolate has been encountered in any case.

5. Experimentally and clinically, the early phases of healing are somewhat slower with homogenous grafts than with autogenous grafts. Therefore, it is important that immobilization be continued over a longer period of time.

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DISCUSSION

DR. ALBERTO INCLÁN, HAVANA, CUBA: It is a great privilege for me to open the discussion on the interesting papers just presented by Dr. Reynolds and Dr. Oliver, and by Dr. Weaver. This privilege is probably due to my previous work in the use of preserved bone for grafting purposes.

Up to a year ago, when we were able to obtain a deep freezer and organize a bone bank, we kept our bone in citrated blood at a temperature of 2 degrees centigrade in a domestic refrigerator. It is gratifying to know that bone banks are being developed in many hospitals.

I have no personal experience with the use of antiseptics and bacteriostatic solutions as preserving agents for homogenous bone. The technique used by Dr. Reynolds and Dr. Oliver is similar to that published by Brown and DeMere for a cartilage bank.

The authors' recommendation of their method of bone preservation is based upon their belief that all transplanted bone is dead bone. We do not entirely agree with this statement. More knowledge is necessary to decide this controversial point. Fresh transplanted bone seems to be rapidly revascularized before its cells have suffered necrosis. Histological examination of bone kept under refrigeration has demonstrated the preservation, for a certain period of time, of the characteristics of normal bone cells, which may mean that this tissue is capable of life if revascularization can be obtained within the proper time. The condition of the recipient bone must be considered of the utmost importance.

The recent experimental work of Kiehn, Friedell, and MacIntyre, of Western Reserve University ("Study of the Vitality of Tissue Transplants by Means of Radioactive Phosphorus", Plastic and Reconstruct. Surg., **3**: 335–339, 1948) should be emphasized, since they concluded that fresh cancellous bone exists "as a vital graft, forming its own blood supply and integrating itself as a vital part of the system from the time it is transplanted. This is shown by the immediate assimilation of P^{32} by the vital grafts, as compared to low uptake by the devital transplants" (boiled bone). Kiehn and his associates also observed that "refrigeration may not depress the recovery of transplanted bone beyond a short initial stage".

More time will be necessary to evaluate the use of this new method of bone preservation. Changing the solutions every two weeks with frequent manipulation, as well as the possibility of the recipient's intolerance to mercurials, must be considered as possible disadvantages.

Dr. Weaver presents a very thorough study of the evolution of preserved homogenous bone. It is difficult to evaluate his results, due to the different types of operations performed and the various grafting materials utilized.

Use of a bone graft in an infected recipient bone will naturally increase the percentage of infection. I wouldn't consider the rather high incidence of infection reported by Dr. Weaver as meaning a greatly increased danger of infection with the use of preserved bone, although he has not done bacteriological tests. In his series, infection developed in only one case which had previously been clean.

I agree with Dr. Weaver's statement that many factors in the postoperative evolution of bone-grafting are of importance in the production of failure. To those he has mentioned must be added an inaccurate fitting of the graft in the treatment of non-union of fractures. When using inlay grafts, I adhere to the principles recommended by the late Fred H. Albee. In many cases we add a dual graft, one of cancellous bone, as the best solution for some ununited fractures.

We lost one graft in our last thirty cases, using homogenous bone from the deep freezer. The patient, with a tuberculous hip ready for a Brittain extra-articular fusion, had a deep tuberculous abscess. Still, the implantation of the graft was carried out and suppuration and disintegration of the graft was the result. The preserved bone graft must not be blamed for this failure, but rather poor judgment in its use.

I have always expressed the opinion that a preserved bone graft should be used only when fresh autogenous bone is not available. However, during my experience with the use of preserved bone grafts, I have found that they can be substituted for fresh autogenous bone transplants. In some of my cases the grafts have been placed in the worst conditions for their integration and growth; still they have acted as well as fresh transplants.

DR. PHILIP D. WILSON, M.D., NEW YORK, N. Y.: I think we are all in agreement that preserved homogenous bone grafts can be used with great advantage in orthopaedic operations. The question that is raised in the paper by Dr. Reynolds and Dr. Oliver is how the bone can best be preserved. They propose immersing it in a chemical solution—namely, merthiolate—in order to prevent bacterial invasion and putrefaction; they claim that this does not affect the osteogenetic properties of the bone, or its toleration in the host tissues. They have experimented with the use of this bone in animals and have a fine exhibit in the scientific-exhibition section of this meeting, which attempts to show what happens.

I have been working with preserved bone grafts since 1946 and, like Drs. Weaver, Bush and Garber, and many others, have been using refrigeration in sterile jars, at a temperature of between 10 and 20 degrees below zero centigrade, as the method of preservation. By careful bacteriological control of the material, we have been able to prevent infection. In a series of more than 200 operations in which this bone was used, our loss of bone grafts has been under 2 per cent., which is about the same as when fresh autogenous grafts are used.

My criticism of the merthiolate method of preservation is that, when the bone is immersed in a chemical solution, there is the risk of altering the nature of that bone, because the chemicals are not inert. Even though the solutions are diluted, a foreign, toxic substance has been added which, in spite of attempts to wash it out, remains in the tissue, as is shown by the persistent stain. I believe that this foreign chemical is an

irritant and that it throws a greater burden on the healing powers of the host tissues than is produced when refrigerated bone is used.

The series of cases reported is too small to give a true picture of what happens; but even so, the authors mentioned one case with loss of the graft and another with a draining sinus, although they reported no infections.

Furthermore, the use of a chemical solution definitely destroys vitality in the bone. I am not yet convinced that there is complete absence of life in refrigerated bone, even though the histological studies of the healing grafts show very little evidence of it. The same may be said of the studies of healing of fresh autogenous grafts. There is a great deal of evidence to prove that living cells can resist prolonged exposure at very low temperature,—as, for example, bacteria, leukocytes, and tumor cells. I like to feel, when bone-grafting, that the cells have been given the chance to play a part in the healing.

It seems to me, in this discussion of methods of preservation of bone, that there is great similarity to the early arguments over Lister's antiseptic method as opposed to the aseptic method in operative surgery. I prefer to obtain sterile grafts and to keep them free from contamination, while the authors prefer the antiseptic method. It was a preference for Halsted's technique of using heat-sterilized silk for ligatures and sutures that led many of us to give up the use of chemically sterilized catgut, and we believe that the wounds heal with less reaction, because of the absence of irritation.

The merthiolate method offers only one advantage, in my opinion, over sterile refrigeration,—that is, that it may protect against the transmission of malaria or the virus of hepatitis or syphilis. Such a complication is, however, very rare, and need not be feared when proper precautions are taken. We have had two instances of hepatitis and one of malaria after operations in which refrigerated homogenous bone grafts had been used; but all of these patients had received blood transfusions, and our studies indicated that the blood conveyed the infection and not the bone.

I hope that Dr. Reynolds and Dr. Oliver will continue their work and will give us a later report of results when their series is larger. There is room for many different techniques in surgery, but we would be wise not to avail ourselves of new methods until after they have been thoroughly tried and proved. For this reason I shall continue to employ the method of refrigeration of sterile bone grafts, in preference to the merthiolate method.

I consider Dr. Weaver's paper interesting and worth while. He has done two things that have not previously been reported: First, he has used cadaver bone, and, second, he has shipped refrigerated bone by the dry-ice method to other cities for use by other surgeons. Cadaver bone is difficult to obtain because of legal restrictions. Even when a person wills his body for scientific purposes, it is not permissible to make use of it unless the consent of the next of kin has first been obtained. The law provides that, after death, legal title to the body is vested in the nearest relative. Even when no relative appears to claim the body, it must be kept for a certain period before it can be disposed of. Infection and decomposition set in rapidly, and the safe period in which to obtain the bone is only about six hours. In addition, the bone must be obtained under aseptic conditions similar to those in an operating room, which practically limits the availability of cadaver bone to a death occurring in the hospital. Also, the death must have occurred from some cause other than infection or tumor. All of these limitations have prevented us from using cadaver bone, and Dr. Weaver is to be congratulated upon solving these problems. Our own stock has been maintained by donations from patients undergoing operations where bone must be excised, and from amputated limbs. Resected ribs from operations upon the chest are also a valuable source of material for the bone bank.

I think Dr. Weaver is perhaps a little discouraged, and unnecessarily so, over his failures. The number of infections was larger than is desirable, but this was largely because he was pioneering and had not developed an adequate method of storing and sealing his bone material against infection. Also, he did not employ careful bacteriological control. I am sure that his results will improve, now that his bone bank is better organized and checked.

Finally, I would like to say a word about the healing properties of refrigerated bone or preserved bone in comparison with fresh autogenous bone. No one can say at the present time that preserved bone serves in all respects equally as well as fresh autogenous bone. It certainly serves well for packing bone cavities in which healing is going on, and I think the results are comparable. Whether it serves as well for cancellous or cortical grafts, we cannot as yet answer. Much more remains to be learned, and it will require many years of experience before we can determine its exact field of usefulness. That preserved bone has a field of usefulness is the only thing I would dare to be dogmatic about at present.

I wish to thank the speakers for their valuable presentations, and to express my pleasure at the privilege of having been invited to discuss them.

DR. FRED C. REYNOLDS (closing): Concerning Dr. Inclán's discussion, the report of Kiehn, Friedell, and MacIntyre in regard to the assimilation of P^{32} does not necessarily demonstrate that fresh cancellous bone exists as a vital graft. In all probability, this only indicates the speed of revascularization of the types of grafts they have used. These observations correspond very well with our experimental findings.

(Continued on page 814)

CAUSES FOR AMPUTATIONS PERFORMED AT WALTER REED GENERAL HOSPITAL DURING 1947 AND 1948*

BY COLONEL AUGUST W. SPITTLER AND LIEUTENANT COLONEL LLOYD W. TAYLOR

Medical Corps, United States Army

In this survey, the cases of 293 patients were studied, who had had a total of 304 extremities amputated. Eighty-two of these cases were excluded from the survey for such reasons as insufficient information available on battle-casualty records, or because final results had not yet been obtained on patients still in the Hospital. This left a total of 211 patients studied, in whom 220 extremities had been amputated (Table I). Two hundred and six of these patients had suffered from battle or other injuries; only five

TABLE I

AMPUTATIONS PERFORMED AT WALTER REED GENERAL HOSPITAL DURING 1947 AND 1948

Disease or Injury	No. of Patients
Vascular disease	
Thrombo-angiitis obliterans	1
Buerger's disease	1
Tumor	
Osteochondrosarcoma	1
Undifferentiated sarcoma	1
Synovioma	1
Injuries from battle	150
Other injuries	56
Total	211

TABLE II

ORIGINAL INJURY TO EXTREMITY

Involvement	No. of Extremities
Nerve only	3
Bone only	9
Muscle and vessel	4
Bone and nerve	11
Bone and muscle	116
Bone and vessel	6
Bone, nerve, and vessel	3
Bone, nerve, and muscle	24
Bone, nerve, muscle, and vessel	39
Total	215

amputations were for vascular disease or tumor. The cases selected for study represent a fair cross section of the amputations performed during 1947 and 1948 at Walter Reed General Hospital.

The type of original injury, as to bone, nerve, muscle, or vessel involved, is shown in Table II.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1949.

TABLE III

NERVE INJURIES IN EIGHTY EXTREMITIES

Nerve Involved	No. of Times Nerve Was Involved
Femoral	3
Sciatic	25
Peroneal	30
Tibial	32
Plantar	3
Brachial plexus	2
Radial	10
Median	11
Ulnar	10
Total	126

TABLE IV

BONE INJURIES

Site of Injury	No. of Extremities
Foot	16
Foot and leg	67
Foot and thigh	1
Foot, leg, and thigh	17
Leg	39
Leg and thigh	24
Thigh	28
Hand	3
Hand and forearm	8
Hand, forearm, and arm	1
Forearm	2
Forearm and arm	2
Total	208

There were nerve injuries in eighty extremities, 126 nerves being affected (Table III). Traumatic amputations were included in this total.

A hand which is completely anaesthetic is a major disability and is a cause for amputation. This is equally true of a foot with a completely anaesthetic plantar surface which ulcerates as a result of weight-bearing. Ten cases of this type were observed, in which the sole cause for amputation was an anaesthetic foot, with areas of local necrosis on weight-bearing, secondary to an irreparable injury to the tibial or sciatic nerve.

The sites of the original bone injury are shown in Table IV. There were bone injuries in 208 extremities in this series.

The major causes for amputation were: gas gangrene, traumatic loss of limb, osteomyelitis, vascular insufficiency, joint lesions, shortening, muscle damage, non-union, an unsatisfactory weight-bearing surface, and paralysis or nerve injury. Other than gas gangrene, traumatic loss of limb, and vascular insufficiency, no single cause listed accounted for amputation. Table V shows the combination of causes.

Amputations were performed upon eight patients because of gas gangrene, secondary to extensive injuries of the extremities. The guillotine amputation had been performed before these patients arrived at Walter Reed General Hospital. Guillotine amputation played an important part in the treatment of the 220 amputated extremities, as evidenced by the fact that a guillotine amputation was performed on ninety-eight extremities at

TABLE V

CAUSES FOR AMPUTATION OF INJURED EXTREMITIES

	No. of Extremities
Osteomyelitis and joint lesion	11
Osteomyelitis and nerve injury	5
Osteomyelitis, joint lesion, and muscle damage	12
Osteomyelitis, joint lesion, muscle damage, and vascular insufficiency	16
Osteomyelitis, joint lesion, shortening, muscle damage, and non-union	30
Osteomyelitis, joint lesion, nerve injury, muscle damage, and vascular insufficiency	18
Osteomyelitis, joint lesion, nerve injury, muscle damage, and unsatisfactory weight-bearing surface	4
Osteomyelitis, joint lesion, and unsatisfactory weight-bearing surface	12
Osteomyelitis, nerve injury, vascular insufficiency, and muscle damage	10
Osteomyelitis, nerve injury, vascular insufficiency, shortening, non-union, and muscle damage	12
Osteomyelitis, shortening, non-union, and muscle damage	35
Gas gangrene	8
Traumatic loss of limb	18
Vascular insufficiency (due to injury)	8
Nerve injury, vascular insufficiency, joint lesion, and muscle damage	6
Nerve injury and unsatisfactory weight-bearing surface	10
Total	215

some time during treatment. Fifty-eight of these were performed at Walter Reed General Hospital and forty at other hospitals.

Although no amputations were performed for osteomyelitis alone, this disease is the major contributing cause for amputation (Table V). The authors believe that sulfonamides and other antibiotics have contributed little, if at all, to the cure of chronic draining osteomyelitis in adults, although they do give systemic benefit during an acute flare-up of osteomyelitis. Adequate surgery and drainage are still the treatment of choice.

Nine patients in this series had both lower extremities amputated; eight of them had been in the hospital from two to four and one-half years to save a defective contralateral limb. The average rehabilitation period after removal of the poorly functioning, painful extremity was less than four months. Amputation of one extremity is not a contra-indication to amputation of a poorly functioning, painful contralateral extremity. The same criteria for amputation should be applied to each extremity.

Sixteen Syme amputations were performed on patients with unsatisfactory weight-

TABLE VI

TIME ANALYSIS OF HOSPITALIZATION

Group	Extremities		Interval between Injury and Amputation (*Months*)	Average No. of Operations Prior to Amputation	Interval between Final Amputation and Rehabilitation (*Months*)
	(*No.*)	(*Per cent.*)			
A	5	2.3	48 and over	16.4	3
B	5	2.3	42 through 47	12.4	4
C	23	10.7	36 through 41	10.0	4½
D	36	16.7	30 through 35	9.0	3½
E	59	27.4	24 through 29	8.0	4
F	28	13.0	18 through 23	7.0	4
G	8	3.7	12 through 17	7.0	4
H	4	1.9	7 through 11	3.0	4
I	47	21.9	6 or less	2.0	3

TABLE VII

SITES FOR AMPUTATION IN 211 PATIENTS'

	No. of Amputations
Upper extremity	
Wrist (disarticulation)	1
Below the elbow	9
Above the elbow	8
Forequarter (interscapulothoracic)	1
Lower extremity	
Ankle (Syme)	16
Below the knee	111
Short below the knee (bent knee)	2
Above the knee	53
Above the knee (supracondylar tendoplasty)	5
Above the knee (Gritti-Stokes)	7
Hip (disarticulation)	7
Total	220 *

* This number includes nine bilateral amputations.

bearing surfaces (Table VII). All of the feet had one or more associated conditions, such as osteomyelitis, joint disease, muscle damage, or nerve paralysis. Nine of the amputations were performed because of failure of full-thickness skin grafts, located on weight-bearing surfaces. Skin grafts applied to weight-bearing surfaces almost invariably fail when they are too massive to receive complete protection by the use of special shoes and supports. Six Syme amputations were performed because of painful, incapacitating feet, for which a complete arthrodesis (ankle fusion and triple arthrodesis) had been performed. A Syme amputee walks better and is less disabled than an adult who has had a foot injury severe enough to require panarthrodesis. Almost invariably these severe foot injuries were associated with traumatic arthritis and periarticular fibrosis of the remaining joints of the feet.

Table VI shows the time interval between the injury and final amputation, but not the months of mental anguish, chronic infection, and conversion reaction, all in the attempt to save useless extremities. Over 75 per cent. of the extremities had been treated for more than a year before amputation, and in each group an average of between 7 and 16.4 operations had been done on the extremity prior to amputation. Over 72 per cent. of these extremities had been treated for eighteen months or longer with a similar range in number of operations. In almost 60 per cent., the patients had spent over two years in hospitals, averaging from 8 to 16.4 operations on the extremity prior to amputation. It can be safely stated that the percentage of successful end results is in inverse ratio to the number of operations required to produce that result.

In the treatment of amputees where an abdominal belt may be required by the prosthesis, bone grafts should be removed from the iliac crest on the same side as the affected extremity. This is because the abdominal belt rests below the contralateral iliac crest, opposite to the amputated extremity.

In twenty-three patients, the fibula had been sacrificed electively in carrying out the planned reconstruction program of the injured extremity. This method of reconstruction is highly unsuccessful and is believed to be unnecessary in the light of the tremendous progress in cancellous bone-grafting in the past ten years.

The sites of amputation are shown in Table VII. As in most series, the below-the-knee amputation was used most frequently; in nineteen of these cases it was necessary to select a higher site for amputation, because the skin was poor as a result of previous operative scars or skin defects. This was particularly true in those cases in which a weight-

bearing type of amputation, such as a Syme, Gritti-Stokes, or supracondylar tendoplasty, could have been performed if good skin had been present.

In reconstructive surgery on an injured extremity, the possibility of amputation should always be considered; and operative incisions should be planned so that, if amputation becomes necessary, it can be done at the lowest possible level.

CONCLUSIONS

1. Unilateral amputation is not a contra-indication to amputation of the contralateral extremity. The criteria for amputation should be the same for each extremity under consideration.

2. Skin-grafting of any type to full weight-bearing surfaces is so highly unsatisfactory as to condemn the procedure in general.

3. Elective sacrifice of the fibula in a reconstruction program is highly unsatisfactory and unnecessary, in the light of our knowledge of the favorable results from cancellous bone-grafting.

4. A Syme amputation is the best major amputation through the extremity. It is preferable from a functional standpoint to a complete arthrodesis of the foot, or to any amputation through the tarsal region.

5. When amputation is a possibility, surgical incisions should be so placed as to permit amputation at the lowest possible level, should this procedure become necessary at a future date.

6. When amputation is a possibility, the removal of cancellous graft from the ilium should be done on the affected side, and not on the contralateral side.

7. Needless operative procedures which promised little, if any, possibility of success were performed on the patients studied, causing prolonged months and years of hospitalization, psychological trauma, conversion reaction, and general systemic damage, secondary to prolonged periods of chronic infection. Early evaluation of these cases and the application of sound surgical principles could have prevented a large proportion of these undesirable problems. The principle most often disregarded in these cases was that amputation is a sound method of treatment and not a last resort.

DISCUSSION

DR. RUFUS H. ALLDREDGE, NEW ORLEANS, LOUISIANA: Colonel Spittler and Colonel Taylor have made an exhaustive study of the causes for amputations in the Army during 1947 and 1948. They have also called attention to some of the most important fundamental aspects in the care of the seriously injured extremity. The authors deserve credit for presenting such an honest statement of the results of surgical treatment which not only failed in the end, but often used up several years of the patient's life.

We still see an occasional War Veteran who, despite several major operations with good immediate results, finally requests amputation, after having carried on fairly well for several years. I agree that it is very important for every case to be carefully evaluated early by experienced surgeons, so that the number of late amputations can be reduced to a minimum.

DR. FRANCIS M. MCKEEVER, LOS ANGELES, CALIFORNIA: The authors have presented over 200 patients, mostly battle casualties of World War II, with severely injured extremities. Included are patients with compound, comminuted fractures, extensive soft-tissue damage, and, in many instances, an associated nerve injury and infection. After attempts to salvage the extremities of these patients by skin grafts, bone grafts, and nerve sutures, amputation was finally resorted to; these represent failures, in the lexicon of reconstructive surgery. It is unfortunate that the authors have not tabulated the percentage of the entire group of battle casualties of World War II which this group of failures represent. It is certain that there is a large group of those injured in battle, with extremities injured just as seriously as those reported in this group, who are still using their arms and legs comfortably and satisfactorily, and for whom a well-planned program of reconstructive surgery was successful.

The point of this paper is, I believe, that a program of reconstructive surgery which is doomed to failure should not be continued indefinitely when the success of a bone graft and multiple-stage, time-consuming operations will result in an extremity so limited in function by joint stiffness, circulatory insufficiency, and impaired sensation that it is a drawback rather than a benefit. The patient should have an amputation

(*Continued on page 819*)

EARLY EFFECTS OF PARTIAL SENSORY DENERVATION OF THE HIP FOR RELIEF OF PAIN IN CHRONIC ARTHRITIS *

BY BENJAMIN E. OBLETZ, M.D., L. MAXWELL LOCKIE, M.D., ELMER MILCH, M.D., AND IRVING HYMAN, M.D., BUFFALO, NEW YORK

From the University of Buffalo School of Medicine and The Buffalo General Hospital

Chronic arthritis of the hip has always been a difficult problem for the orthopaedic surgeon. The many non-operative and surgical procedures which are currently practised are well known and their limitations are recognized. To these procedures may be added the operation of sensory denervation of the hip for the relief of pain. This paper reports the early effects of partial sensory denervation, a procedure which gave some measure of relief from pain to twenty-eight of forty-two patients.

Pain is the major disabling factor in chronic arthritis of the hip, regardless of etiology. Other factors include spasm, deformity, limitation of motion, and weakness. The location, character, and intensity of the pain vary greatly with the individual patient, but there seems to be no correlation between the type of arthritis and the pain pattern. Pain may be constant or intermittent, and may be dull to sharp in quality. Weight-bearing, fatigue, and weather changes usually intensify the pain, while rest, heat, salicylates, and sedatives give temporary relief.

Definite patterns of pain (Fig. 1) can be distinguished:

1. *Obturator Pattern:* The pain is deep in the groin and radiates along the medial aspect of the thigh to the knee. Occasionally it appears to be in the knee, without associated pain in the hip or thigh.

2. *Posterior Pattern:* The pain is in the buttock behind the hip joint, usually without any radiation.

3. *Femoral Pattern:* The pain radiates from the inguinal ligament to the knee, anteriorly.

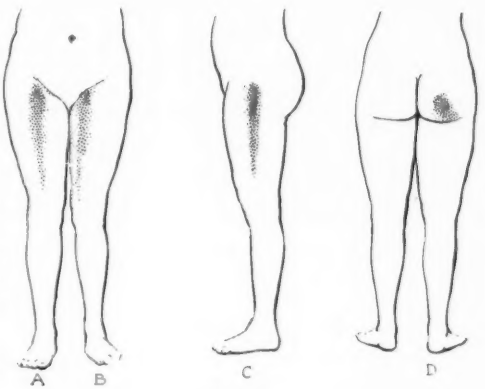

FIG. 1

Common pain patterns in chronic arthritis of the hip. *A*: Femoral pattern (anterior). *C*: Lateral pattern. *B*: Obturator pattern (medial). *D*: Posterior pattern.

4. *Lateral Pattern:* The pain is over the greater trochanter and radiates down the lateral aspect of the thigh to the knee.

The obturator pattern is seen in nearly all patients with painful arthritis of the hip; often it is combined with the posterior pattern. The other patterns are rarely encountered except in conjunction with the obturator pattern.

These pain patterns are reflex manifestations of irritation of the sensory nerves to the hip joint. The location of the reflex pain corresponds to the anatomical distribution of the motor components of these nerves in the thigh and buttock.

The hip joint is supplied by articular branches from three major nerves:

1. *Obturator Nerve:* These branches arise from the ventral divisions of the second, third, and fourth lumbar nerves.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948.

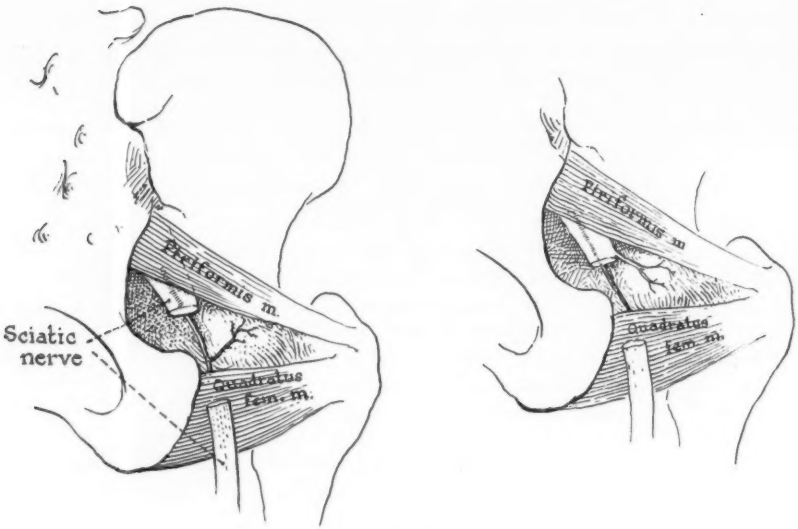

FIG. 2

Posterior sensory nerve supply to the hip joint.
Common pattern is shown at left. The sensory branch arises from the nerve to the quadratus femoris, which is given off by the sciatic nerve.
Anatomical variation is seen at right. The sensory nerve arises as an independent nerve from the sciatic trunk in five of twenty-four dissections performed by Kaiser.

A. *Accessory Obturator Nerve:* These branches arise from the ventral divisions of the third and fourth lumbar nerves, and are present in 20 to 30 per cent. of the individuals.

2. *Femoral Nerve:* These branches arise from the dorsal divisions of the second, third, and fourth lumbar nerves, by way of the branch to the rectus femoris.

3. *Sciatic Nerve:* These branches arise from the two ventral divisions of the fifth lumbar and first sacral nerves, by way of the branch to the quadratus femoris.

Anatomical variations in the distribution of the articular branches from the obturator and accessory obturator nerves are reported in detail by Kaiser. His dissections reveal lesser variations in the capsular branches from the sciatic nerve to the posterior portion of the hip joint (**Fig. 2**). No satisfactory approach to the articular branches of the femoral nerve has been found, and this denervation has not been attempted.

Spasm and contracture of the muscles supplied by the motor components of these nerves produce the flexion, adduction, and external-rotation deformity characteristic of chronic arthritis of the hip. Spasm can be demonstrated objectively by the electromyogram (Figs. 3-A and 3-B). In many of the authors' cases, electromyographic studies were made to determine the presence of tension in the adductor muscles. Recordings were obtained with a six-channel ink-writing oscillograph, which picked up muscle potentials with either surface or needle electrodes. The most effective recordings were obtained when needle electrodes were inserted into the adductor longus muscle of each thigh, the normal side being used as a control. The patient was recumbent in a comfortable position with the thighs supported for complete relaxation.

In normal human muscle in a relaxed state, there is no evidence of electrical activity. Involuntary muscle tension in the form of biphasic spikes was found in a large number of patients with all types of painful arthritis of the hip, tested preoperatively.

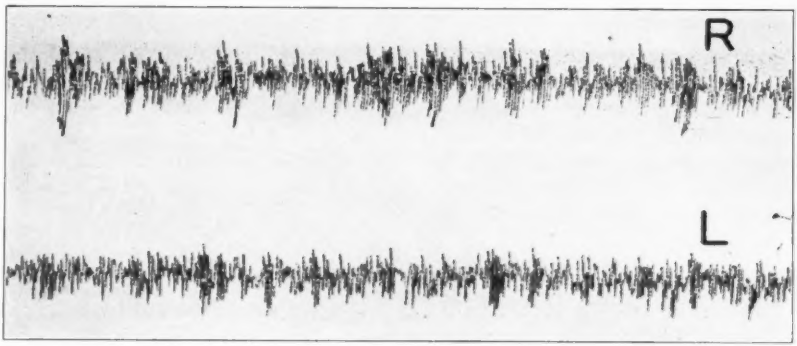

FIG. 3-A

D. O. Electromyographic tracings of spasm in the adductor muscles in a patient with bilateral osteo-arthritis of the hip. Preoperative tracing made on June 17, 1947.

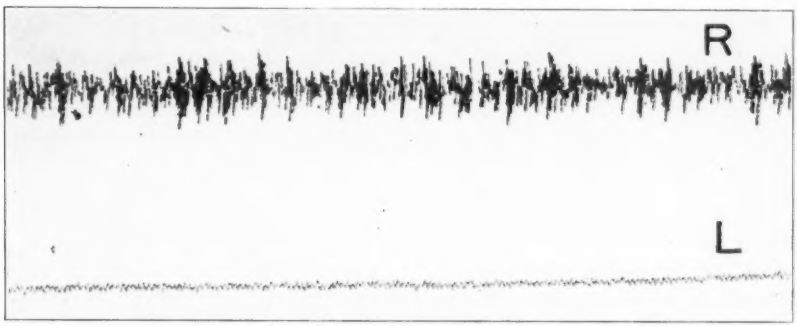

FIG. 3-B

Tracing after intrapelvic section of the left obturator nerve (June 25, 1947).

RATIONALE OF DENERVATION OF THE HIP

Interruption of all pain pathways from the arthritic hip joint to the central nervous system should abolish pain perception. This interruption is possible at different levels and by different approaches. Chordotomy, posterior rhizotomy of the third and fourth lumbar sensory roots, and peripheral sensory denervation of the hip joint have been practised. The least harmful and least difficult operation is that of partial denervation of the hip, which consists of obturator neurotomy and section of the nerve to the quadratus femoris.

Camitz, in 1933, first reported section of the obturator nerve to paralyze spastic adductor muscles in osteo-arthritis of the hip. He was not concerned with interrupting the articular sensory branches of the obturator nerve.

Tavernier and Godinot, in 1945, reported in detail their experience with the surgical treatment of osteo-arthritis of the hip. Between 1934 and 1943, they performed obturator-nerve section on fifty-seven patients. Through an extrapelvic approach, they sectioned the posterior branch and the articular branches of the obturator nerve in twenty-five patients. In the other thirty-two, they sectioned only the articular branches. Immediate results showed relief from pain in forty-five of these patients, but, after a longer observation period, only 38 per cent. still had good relief from pain. Between 1943 and 1945, they combined the obturator-nerve section with section of the nerve to the quadratus femoris. Of twenty-four cases, twenty-two had satisfactory relief from pain. Other surgeons have reported their experience with this operation.

Selection of Patients

The patient selected for denervation is one who has the obturator or posterior pattern of pain, not relieved by conservative therapy, in whom standard orthopaedic reconstruction operations are contra-indicated because of old age, feebleness, obesity, or lack of determination, or because the arthritis is bilateral. The long convalescent period and the economic burden associated with these operations further restrict the indications for reconstructive surgery. Partial denervation of the hip can be performed regardless of these contra-indications.

OPERATIVE METHODS

1. *Obturator Neurotomy*

This can be done by either the intrapelvic approach, advocated by Selig and by Chandler and Seidler, or the extrapelvic approach advocated by Tavernier. By the intrapelvic neurotomy, the entire nerve is sectioned before it gives off its sensory branches to the hip. The exposure is extraperitoneal, and is easier to perform than the extrapelvic approach to the nerve. It is particularly applicable to bilateral cases and is the authors' method of choice.

The extrapelvic approach to the obturator nerve has been advocated by Tavernier and his associates, because it permits section of only the sensory branch, without the adductors being paralyzed. According to their writings, the articular branch is given off laterally from the posterior division of the obturator nerve after it leaves the obturator foramen. No such constancy of distribution has been found in the authors' dissections.

A. *Intrapelvic Approach*

The intrapelvic technique employed by the authors varies only slightly from that described by Chandler and Seidler. The same incision may be used for unilateral or bilateral intrapelvic obturator neurotomy.

Before operation, an indwelling catheter is inserted so as to avoid disturbing the urinary bladder. The operation is performed with the patient in the Trendelenburg position, which permits the extraperitoneal portion of the pelvis to be explored more easily. Complete relaxation of the rectus muscles is essential, and can be achieved through the judicious use of curare by the anaesthetist.

A Pfannenstiel incision is made in the pubic fold (Fig. 5), bounded on each side by the linea semilunaris, including the skin, subcutaneous tissue, and superficial fascia. The rectus sheath is split transversely across the body of both rectus muscles or over only one of them, depending upon whether a bilateral or unilateral neurotomy is to be performed. The distal portion of the rectus muscle is then separated from the anterior sheath by compress dissection. After the lateral border of the rectus has been exposed by means of finger dissection, the bladder and peritoneum are reflected posteriorly and medially; the dissecting finger then sweeps out laterally over the obturator foramen, along the lateral wall of the lesser pelvis, until the nerve is palpated. At this point an aneurysm hook is placed about the nerve and it is gently separated from the surrounding structures by blunt dissection. The nerve is pinched with a clamp to evoke contraction of the adductors and to confirm the identity of the nerve before it is sectioned. At least an inch of the nerve is excised between ligatures. The wound is closed in layers.

Care must be observed not to injure the epigastric vessels when the operator is reflecting the bladder and peritoneum posteriorly and medially.

B. *Extrapelvic Approach*

A vertical incision, five inches long, is made in the upper portion of the thigh at a point halfway between the femoral artery and the symphysis pubis (Fig. 4). The subcutaneous fat is divided and the vaginal fascia of the thigh is split in the line of the incision.

This exposes the lateral border of the adductor longus and the adjacent border of the pectineus. These two muscles are separated and retracted. The obturator nerve is easily found in the interval between these muscles. The anterior branch lies between the adductor longus and the adductor brevis, which is just beneath it. It is traced proximally until the obturator foramen is reached. The obturator nerve divides into anterior and posterior branches, usually after leaving the obturator foramen. Lateral branches from either the anterior or posterior branches are looked for and, when found, are divided. The anterior and posterior branches are cut as close to the obturator foramen as possible, and about one inch of the nerve is resected. The incision is then closed in layers.

2. *Posterior Denervation*

The skin incision is made in the distal two thirds of the line drawn from the posterior superior spine of the ilium to a point halfway between the greater and lesser trochanters (Fig. 6). The subcutaneous fat is divided in this line to expose the glutaeus maximus. The fibers of the glutaeus are split bluntly in their long axis, starting at the greater trochanter. The entire depth of the muscle is divided and retracted forcibly, exposing the subgluteal fatty areolar tissue, in which can be seen the sciatic nerve. The nerve is not disturbed, but the fat covering the quadratus femoris, inferior gemellus, obturator internus, superior gemellus, and piriformis at the intertrochanteric line is divided to expose these muscles. A blunt instrument is introduced under the insertions of the gemelli and obturator internus, and these muscles are divided close to their insertions. They are then reflected upward and medially as far as possible, being best peeled off the underlying hip capsule by compress dissection. Very little bleeding is encountered.

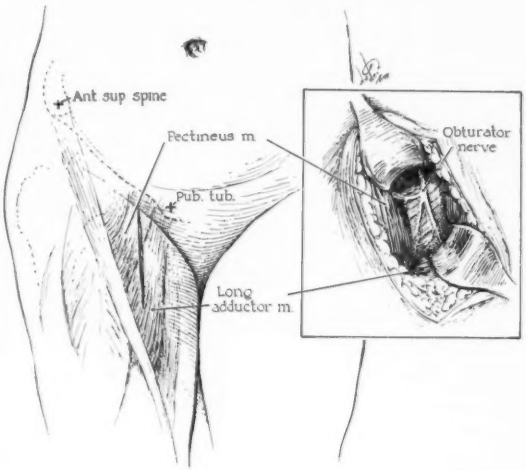

FIG. 4
Extrapelvic technique of obturator neurotomy.

These muscles, when reflected, serve to protect the sciatic nerve from injury. The posterior portion of the hip capsule is thus exposed, with the broad quadratus femoris forming the lower border of the operative field. The nerve to the quadratus femoris can often be palpated as a cordlike structure which runs perpendicular to the muscle and enters the undersurface of the muscle near the ischium. The nerve lies directly on bone and is covered by a very dense fibrous fascia, so that sharp dissection is required to mobilize it. When the nerve has been exposed, it is pinched with a hemostat and the quadratus femoris is seen to contract. The nerve is then cut at the border of the muscle and gently freed proximally by incising the overlying dense fascia. Branches from this nerve to the hip capsule are looked for and, when found, are divided. The nerve is traced back as far as possible, until its origin from the underside of the sciatic nerve is reached or until it disappears under the piriformis. The nerve is divided as high as possible.

The nerve to the inferior gemellus is found, entering the undersurface of the reflected muscle, and is cut at its insertion and traced proximally as far as possible. This nerve may also give rise to articular branches.

Occasionally a large sensory branch comes off the sciatic nerve, just above the nerve

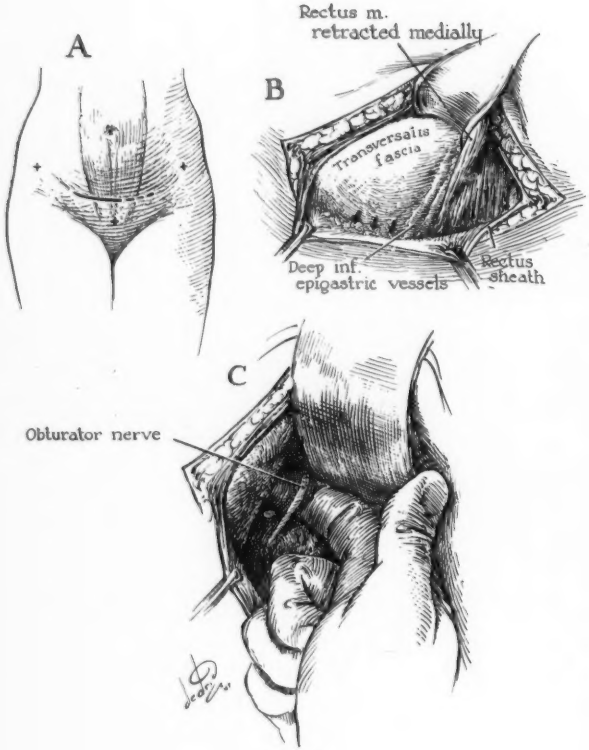

FIG. 5

Intrapelvic technique of obturator neurotomy.

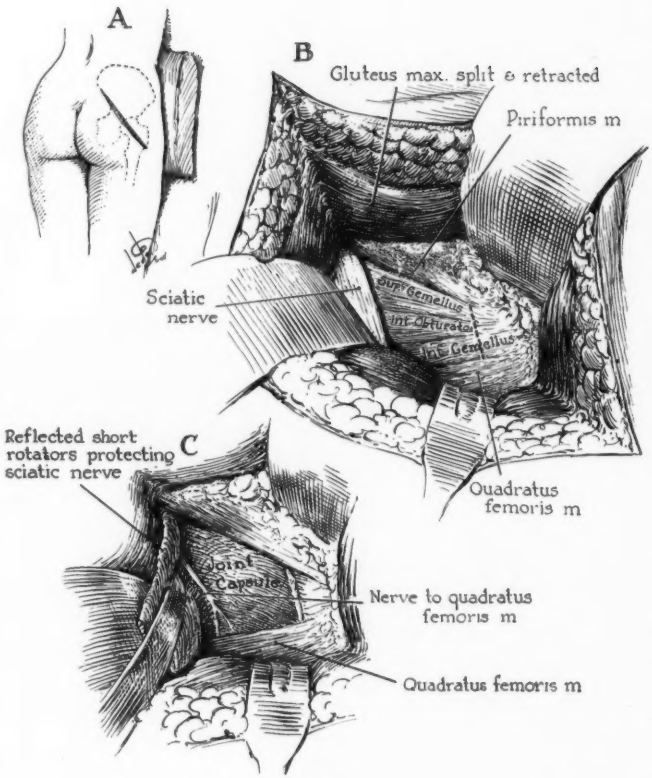

FIG. 6

Posterior denervation of the hip by section of the nerve to the quadratus femoris.

TABLE I

ETIOLOGICAL FACTORS, AGE, AND NUMBER OF FAILURES

	No. of Patients	Average Age (*Years*)	No. of Failures
Osteo-arthritis	24	65	8
Rheumatoid arthritis	5	47	1
Marie-Strümpell disease	3	45	1
Aseptic necrosis			
Post-traumatic	3	40	1
Idiopathic	4		
Congenital dislocation	2	38	2
Old Perthes' disease	1	40	1
Totals	42		14

to the quadratus femoris, and runs parallel to this nerve as far as the hip joint, where it divides into small branches and enters the hip capsule. This nerve must be looked for and, if found, resected. It was present in five of twenty-four dissections made by Kaiser [4].

The divided and reflected rotator muscles are then sutured to their place of insertion at the greater trochanter. The glutaeus maximus fibers come together easily, and the thin overlying fascia is sutured loosely. Subcutaneous and skin closures are performed in the usual manner. No drains are needed.

The intrapelvic obturator neurotomy and posterior denervation are performed as one operation, bilaterally if desired. The postoperative care is simple, and the patient may sit up or even get out of bed on the day after the operation. The usual period of hospitalization is from eight to ten days. No serious operative complications have been experienced.

This report is based upon experience with partial denervation of forty-eight hips in forty-two patients, treated between May 1946 and October 1947 (Table I). In all instances the arthritic changes in the hip joint were well advanced clinically and roentgenographically. Conservative therapy had been tried without benefit in all of these patients. The

TABLE II

OPERATIVE PROCEDURES

	Relief	No Relief
Obturator neurotomy		
Intrapelvic	10	2
Extrapelvic	10	11
Posterior denervation	2	0
Combined one-stage partial denervation	6	1
Totals	28 (67%)	14

earliest cases were treated only by extrapelvic obturator neurotomy. After several failures, the authors changed to the intrapelvic obturator-nerve section with better results. In patients with the obturator pattern of pain, only the intrapelvic obturator-nerve section appeared to give relief. Two patients with the posterior pattern of pain were relieved by posterior denervation alone. Patients with the obturator pattern plus posterior or other patterns of pain were subjected to the combined operation of intrapelvic obturator neurotomy plus posterior denervation. Some of these operations were done in two stages, and it was possible to evaluate the early effects of the obturator neurotomy before the posterior denervation was performed. In the last seven patients the combined operation was per-

formed in one stage, with satisfactory relief of pain in six patients (Table II). In this series, no attempt was made to locate and section the accessory obturator nerve.

EARLY EFFECTS OF PARTIAL DENERVATION OF THE HIP

Not enough time has elapsed to permit a final evaluation of the results of this operation. Since they were based on an observation period of from three to twenty months, we can record our impressions only of the early effects. It is hoped that further observation and experience will permit a more valuable end-result study.

Pain

Accurate evaluation is not possible, because of the subjective nature of the response. Complete relief from pain is rarely acknowledged, but partial relief is accepted with gratitude by most patients in whom the operation succeeded. Residual postoperative pain is usually of a milder character and a different pattern than the preoperative hip pain. Patients with the obturator pattern of pain may get relief from obturator neurotomy, only to be aware of pain of lesser intensity in other locations about the hip joint.

An estimate of the relief from pain may be obtained by the diminished need for aspirin or sedatives, or by the degree of relief noted by other members of the family when the patient is recumbent, sitting, or walking. Some patients, who felt no improvement in the hip pain when walking, reported relief while at rest. Most reported that they slept better.

The earliest effect of the operation on pain is seen almost as soon as the patient recovers from the anaesthesia. Pain in the operative areas does not mask the relief from deep hip pain. Radiating thigh pain disappears, along with a feeling of tenseness in the thigh.

Range of Motion

In very few of the patients has there been a measurable increase in hip motion after this operation. Most, however, have been able to abduct their legs better and to assume a broader stance. Others reported that they were able to put on their shoes and stockings after the operation, a procedure prohibited previously by pain. This was a welcome improvement.

Spasm

The patient is aware of relief from tension in the adductor region as soon as he recovers from the anaesthetic. This is verified by postoperative electromyographic tracings, which show almost complete disappearance of the previously observed spontaneous muscle activity.

Strength

One detrimental early effect of the obturator neurotomy is the weakness in flexion of the hip in a few patients, due to the loss of reinforcing flexion action of the adductor longus and adductor brevis. This weakness has not added to the disability of these patients.

Sensation

Postoperative neurological examination showed an area of diminished sensation over the medial aspect of the thigh, just above the knee, in a few patients. They complained of numbness in this area.

Deformity

The operation has not corrected any existing deformity. Undoubtedly the persistent attitude of flexion, adduction, and external rotation is due to fixed contractures, and is not influenced by the release of spasm of the involved muscles. Irregularity of the articulating surfaces of the hip joint also influences the deformity and this, of course, is not altered by the denervation procedure.

Shortening

Shortening is not influenced by the operation.

Joint Changes

Follow-up roentgenograms have not disclosed any changes in the arthritic process. More time will be needed to evaluate the effect of the operation on the course of the arthritis of the hip.

In fourteen of the forty-two patients, absolutely no relief from pain was experienced. Most of these failures were in patients treated by the extrapelvic obturator neurotomy. Reoperation was not done. The authors could not predict success or failure in any patient before surgery.

CONCLUSIONS

Partial denervation of the hip has been performed for the relief of pain in various types of chronic arthritis of the hip. This operation consists of an intrapelvic obturator neurotomy and section of the nerve to the quadratus femoris. It is relatively easy to perform and produces no constitutional reaction, so that it is applicable to a large group of patients.

Of forty-two patients with painful arthritis of the hip who were thus treated, satisfactory relief from pain was obtained in twenty-eight. The longest postoperative observation period was twenty months. When obturator neurotomy alone was used for the relief of pain, it was found that the intrapelvic approach was more effective than the extrapelvic operation. Eleven of the fourteen failures in this series were treated by extrapelvic obturator-nerve section. Lack of consistently satisfactory results may be attributed to anatomical variations in the sensory nerve supply to the hip.

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DISCUSSION

Dr. Emanuel B. Kaplan, Bronx, New York: Dr. Obletz' paper is very interesting and timely. This method, which was initiated in Sweden and used widely in France, is a useful one. We had a patient with Marie-Strümpell disease upon whom we tried the method in 1945, by the extrapelvic route, on one hip. The patient felt so well that he asked us to do the operation on the other side. The result was so satisfactory that he returned to his work as a gardener. Since then we have operated upon fifty-four patients, the results of which will be published shortly, and we have now operated upon twenty more. We have used only the extrapelvic method, because it appeared more simple. It is important to place the incision along the lateral border of the adductor longus in order to locate the obturator nerve in the interspace between the adductor longus and the pectineus. It is easy to identify the two branches of the nerve in the areolar tissue in this area.

The posterior route, which we have used in three cases only, is slightly more difficult. As Dr. Obletz said, it is necessary to extirpate the nerve to the quadratus femoris. We use a slightly different approach, which we think is simpler. With the apex of a semicircle over the greater trochanter, one branch goes down to the femur and the other is almost parallel to the fibers of the glutaeus maximus. Through this incision we cut the femoral insertion of the glutaeus maximus. This is an area where bleeding occurs. Bleeding is much

easier to control when the glutaeus maximus is freely retracted. We have to be extremely careful because the inferior gluteal artery may be injured, resulting in severe bleeding.

This method opens new horizons as to understanding of pain in joints. We all think that the ordinary articular nerve branches are going the way they have been described by Dr. Obletz and many anatomists. Not much is known about the microscopic endings of those nerves. We have absolutely no idea how the pain stimuli are carried to the central nervous system. Investigations show that rhizotomies and peripheral-nerve section do not prevent the experimental animal from having painful sensations as a result of irritation of the extremities.

In the posterior approach, Dr. Obletz divides not only the nerve to the quadratus femoris, but also the external rotator muscles; in the anterior approach, the nerve supply to the adductor muscles. It is possible that he thus interrupts the sensory nerves to the muscles and the motor nerves, which would amount to indirect tenotomies.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: I have used this operation for over fifteen years for pain in the hip. Roy Abbott and others use it for spastic conditions of the adductor muscles. The intrapelvic approach was described by Selig about 1915. The reason that it has not been discussed in the American literature is probably because the results are so uncertain. In many cases the results are satisfactory, but one cannot predict what will happen when an obturator neurectomy is done for the relief of pain.

The operation is relatively simple, but the obturator muscles cannot be denervated without producing weakness of the adductor muscles. If both branches are cut, the patients are unable to cross their legs while sitting, they lack endurance in walking, and some of them lack stability. For that reason I have felt that I would return to the external route and cut only the deep or posterior branch. If there is a strong adductor contracture, I divide both branches. Dr. Reynolds and I have reported twenty cases done by the intrapelvic route; sixteen patients had what we thought were satisfactory results over a short period, but none of them have been operated upon for longer than two years. Many of those whom we regarded as satisfactory have a weak limb.

For several years I have combined the obturator neurectomy with a Smith-Petersen acetabuloplasty and have obtained more satisfactory results than with either operation alone. The more I operate on these old painful hips in older people, the more I am inclined to consider that the best therapy is a cane or a crutch. That you can depend on, with rest. If the patient will not rest and demands an operation, obturator resection is a relatively simple procedure and it usually gives about 50 per cent. relief of symptoms. It does not give complete relief, and it may leave objectionable weakness of the extremity.

DISCUSSION

USE OF HOMOGENOUS BONE AND OF THE MERTHIOLATE BONE BANK

(*Continued from page 799*)

I should like to correct Dr. Wilson in that we claim no infection in a clean case, but have had persistent drainage in infected cases. Experimentally and clinically, there has been no evidence of tissue sensitivity or toxicity from aqueous merthiolate solution, used as a preserving agent for bone.

DR. JAMES B. WEAVER (closing): It is a privilege to have my paper discussed by such eminent authorities as Dr. Inclán and Dr. Wilson. I am in complete agreement with Dr. Inclán's remarks.

Dr. Wilson feels that I am somewhat discouraged. Let us say that I am not so enthusiastic as I was at one time, but this change is for the better. One of my first cases was the last one reported in my paper (Case 6-S),—the repair of a large bone defect in the tibia, caused by osteomyelitis. The result was truly remarkable, and led us to use preserved homogenous grafts with the expectation that they would accomplish more than we had ever expected from autogenous grafts. This was based on the assumption that an ample supply of graft material might offer a greater chance of success. This assumption is in part true, but basic principles in bone-graft surgery must be observed. I am continuing the use of preserved homogenous grafts.

This is a small series and the statistics are apt to be misleading. This is particularly true if one notes only the percentage, and does not take into consideration the large number of difficult cases.

OBTURATOR NEURECTOMY FOR COXALGIA

An Anatomical Study of the Obturator and the Accessory Obturator Nerves

BY ROBERT A. KAISER, M.D., BUFFALO, NEW YORK

From the Department of Orthopaedic Surgery, Edward J. Meyer Memorial Hospital, Buffalo, and the Department of Anatomy, University of Buffalo School of Medicine

The anatomy of the hip joint in terms of its nerve supply has, in recent years, received much attention. This has been directly due to the reports of Tavernier and his associates, indicating that surgical attack on the sensory fibers to the hip joint from the obturator nerve and the nerve to the quadratus femoris could not only be accomplished, but was attended by good results in patients with painful hip disorders. In the elderly, frequently obese, patient with coxalgia, biologically unsuited for a major surgical procedure such as arthrodesis, these operations appeared to offer a simple solution for a difficult problem.

Frequently, however, the operating surgeon does not seek out the capsular fibers, but contents himself with the less tedious task of sectioning either the obturator nerve or the nerve to the quadratus femoris, feeling secure that his level of section is above the point at which capsular fibers are given off. This approach makes the evaluation of these operations difficult. Successful results could be attributed to factors other than depriving the capsule of part of its sensory innervation. Relief might be obtained, following surgery, from the accompanying denervation of deforming muscle masses (adductors and external rotators), thus relieving spasm or correcting muscle imbalance.

Until a large series of cases have been reported in which surgical attention is directed exclusively to the sensory fibers to the capsule, and an equally large control series are studied in which the sensory fibers are avoided, but the muscular branches are severed, the results will be questionable. Before either of these studies can be accomplished, it becomes necessary to scrutinize certain aspects of the neural anatomy of the hip joint.

Obturator Nerve

In current, standard anatomy texts and recent publications, one finds not only a divergence of opinion regarding the capsular fibers, but a certain vagueness about their course and distribution. The anatomies of Gray, Grant, Morris, Cunningham, and Piersol cite the anterior branch of the obturator as the source of the sensory fibers. Piersol's *Anatomy* mentions, in addition, a branch from the posterior. The fibers are described variously as going to the hip joint, the acetabular notch, or the anteromedial portion of the capsule. Tavernier and Godinot favor the posterior branch as the most frequent point of origin for these fibers which, they state, supply the anterior portion of the hip capsule, the head of the femur, and the acetabulum. Kaplan, on the basis of twenty-four dissections, found that the capsular branches of the obturator nerve came, most frequently, from the common obturator trunk in the obturator canal. Gardner confirmed this observation after seven complete and four partial dissections of adult joints, in addition to the study of serial sections of four foetal joints.

In an effort to obtain a more exact and detailed picture of the nerves to the hip joint from the obturator and accessory obturator nerves, dissections were undertaken. Four preliminary exercises were done to determine what method of attack might best lend itself to the demonstration of these branches. Finally the following procedure was adopted: Cadavera were transected through the lumbar and upper femoral areas and then split sagittally through the mid-line. The peritoneum and pelvic organs were stripped from these hemipelves, and the obturator nerve was traced from its emergence from behind the psoas muscle to the obturator canal. The iliopsoas was reflected laterally, and the

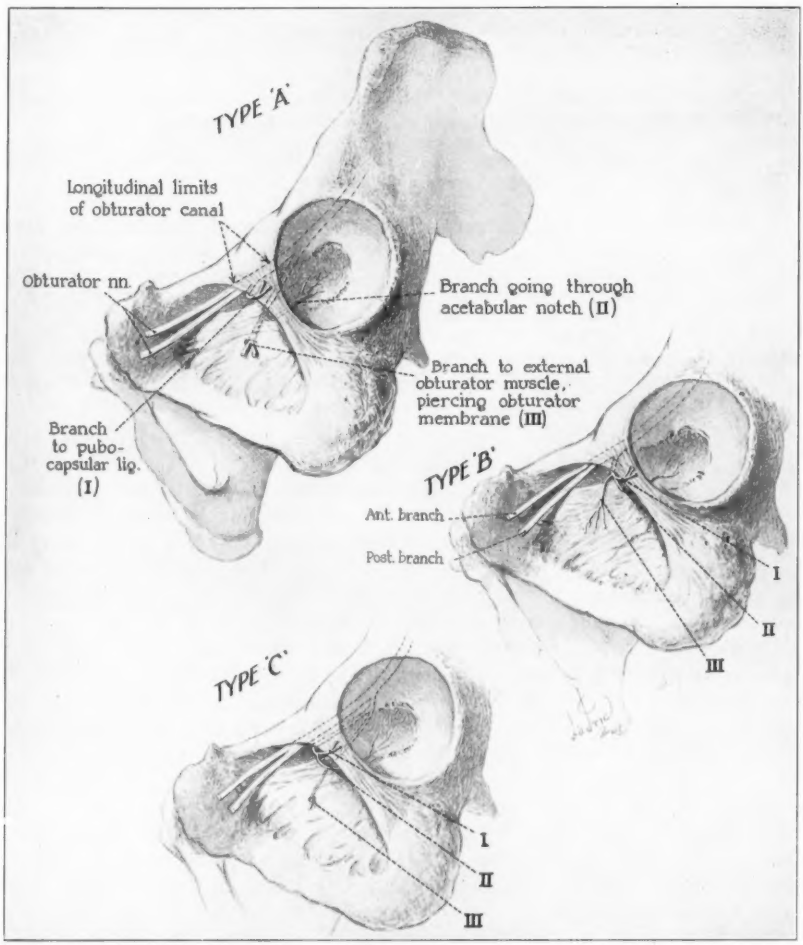

FIG. 1

Three basic patterns of innervation of the pubocapsular ligament and the acetabular notch from the obturator nerve.

region of the iliopectineal eminence was inspected for an accessory obturator nerve. The obturator internus and its fascia, in each instance, was carefully freed from the obturator membrane to facilitate the tracing of those branches which took origin in the pelvis. After all relationships had been observed, the horizontal ramus of the pubis was removed; the canal was cleared of fat; and the fibers picked up to this point were followed to their terminations. Twenty-four dissections were done in this standard fashion. Most of the specimens were photographed for future reference, and a few of the finest filaments traced to the capsule were subjected to histological study, to be sure that dissection continuity could be relied upon. No statistical values can be derived from such a small number of observations, but the findings seem to be of some clinical value.

Two branches of the obturator nerve were frequently encountered, which demand description and re-emphasis. In reference to hip-joint innervation, these are much more important than either the anterior or the posterior branch. The first has been described

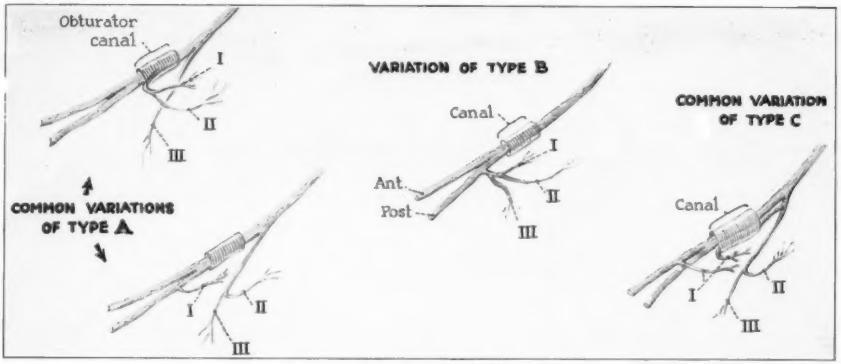

FIG. 2

Variations of the three basic patterns.
I: Branch to the pubocapsular ligament.
II: Branch going through the acetabular notch.
III: Branch supplying the obturator externus.

by Kaplan and by Gardner; it takes its origin from the obturator nerve in the canal, from whence it passes, hugging the lateral bony aspect of the passage, to the pubocapsular ligament which is directly adjacent to the outlet of the obturator canal.

From time to time this branch had a double destination, supplying the capsular area and then passing posteriorly over the transverse acetabular ligament and into the acetabular notch, presumably to supply the ligamentum teres. *One should not get the impression that this branch is consistently given off near the outlet of the canal, for it may be found leaving the obturator nerve anywhere in the canal and, as a matter of fact, frequently is found at the inlet of the passage. Nor should one feel that the nerve becomes clearly visible simply by tracing the anterior or posterior branch back to the common trunk.*

The second branch of prime importance is large in size and quite constant; it was present in eighteen of the twenty-four specimens. It originates from the obturator nerve inside the pelvis. In one instance it was found leaving the main nerve as far as 3.5 centimeters from the mouth of the obturator canal. The usual course of this branch is to the entrance of the canal, at which point it dips down between the obturator internus and the obturator membrane, piercing the latter to supply the obturator externus. Frequently a filament is given off before the obturator membrane is passed, which courses directly to the acetabular notch. In six instances this branch bifurcated within the pelvis. One component accompanied the common trunk through the canal to supply the pubofemoral ligament. The other pursued the usual path to the obturator externus. In these instances the acetabular notch was supplied by either branch.

Consideration of the variations (Fig. 2) will make clear that infrequently the anterior or the posterior branches do supply the capsule. This confirms the findings, but not the frequency, recorded in standard texts and by Tavernier and Godinot.

The detailed findings of the dissections are presented in Figures 1, 2, and 3. For the sake of simplicity, the patterns of innervation have arbitrarily been broken down into three basic types, *A*, *B*, and *C* (Fig. 1). *Type A* was found six times. In two instances the general arrangement was the same, except that the single branch to the pubocapsular ligament came not from the common nerve, but from the posterior branch. Another variation occurred three times,—the branch to the pubocapsular ligament supplied the acetabular notch as well. *Type B* was observed four times. One variation occurred in a specimen in which the posterior branch supplied the pubocapsular ligament and the acetabular notch. *Type C* was present four times. A variation was found in two hips in

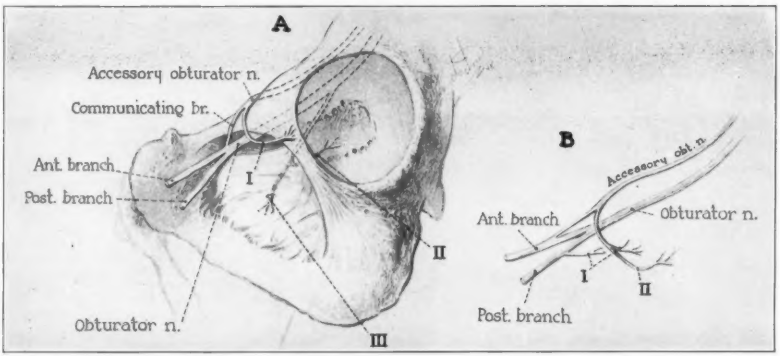

FIG. 3

Accessory obturator nerves.
I: Branch to the pubocapsular ligament.
II: Branch going through the acetabular notch.
III: Branch supplying the obturator externus.

which the acetabular notch was innervated by a filament from the nerve to the obturator externus. The pubocapsular ligament was supplied, not only by a branch derived endopelvically, but also by a filament from the anterior branch of the obturator nerve.

Accessory Obturator Nerve

The accessory obturator nerve is reported to occur in from 19 per cent.[8] to 29 per cent. of cases[6]. There is general agreement that this nerve, when present, supplies the capsule of the hip joint. In only two specimens was this structure present (Fig. 3). In *A* the accessory obturator splits and gives a branch to the common obturator nerve, while the other branch lavishly supplies the pubocapsular ligament. The branch to the acetabular notch is derived from the nerve to the obturator externus, which took its origin within the pelvis. In the second specimen (*B*) one branch of the bifurcated accessory obturator fuses with the anterior branch of the obturator. The other courses not only to the pubocapsular ligament, but also to the acetabular notch. In this dissection, an additional branch to the pubocapsular ligament from the posterior branch of the obturator nerve was in evidence.

In these two instances the capsular area supplied by the accessory obturator was about the same as that supplied by the obturator alone. This is at variance with the statement of Gardner: "When the accessory nerve is not present, this region of the capsule is reached by the femoral nerve . . ."

COMMENT

It would seem from this study that the nerve supply to the hip from the obturator and accessory obturator nerves is a trifle more complicated and variable than has generally been indicated. It would appear that the extrapelvic approach to the capsular branches is inadequate. In those instances where the exit of the obturator canal is adequately explored and the capsular fibers are identified and sectioned, there is still a good possibility that the nerve to the acetabular notch is present. Also, the presence of an accessory obturator nerve must be kept in mind.

If the intrapelvic approach is utilized, one has an excellent chance of sectioning the obturator nerve above the point where the sensory fibers are given off. However, without exploration of the region of the iliopectineal eminence for an accessory obturator, as recommended by de Sousa, one cannot be sure that the sensory area of the capsule sup-

plied by the obturator and accessory obturator nerves is denervated. There is a remote possibility that, due to poor exposure or poor hemostasis, the obturator nerve could be sectioned near or at the mouth of the obturator canal, with the large branch to the obturator externus, originating endopelvically (which may supply the acetabular notch and the pubocapsular ligament), going free.

NOTE: The author wishes to thank Benjamin E. Obletz, M.D., for his encouragement of this project; and Oliver P. Jones, Ph.D., Professor and Head of the Department of Anatomy, University of Buffalo School of Medicine, for the materials used and advice given. Appreciation is also given to Mr. M. Diedrick for his careful attention to the illustrations.

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DISCUSSION

CAUSES FOR AMPUTATION

(*Continued from page 804*)

rather than endure the psychological devastation and economic loss resulting from a long period of hospitalization and multiple surgical procedures, and then finally have an amputation. Particularly is this the case when only one extremity is involved. With this, I am in accord. However, immediate or even early decision to amputate an injured extremity is often wrong. Many times, such a decision cannot be made intelligently for many weeks or months after the injury, particularly in young individuals. Often the decision cannot fairly be made until a program of reconstruction has been tried and has failed during some phase of its development.

I feel that the authors' statement that the fibula is useless in reconstruction of the leg is not tenable. True, the fibula in an adult cannot be expected to take over the entire weight-bearing function of the tibia, as it will not become hypertrophied to that degree. In many instances, however, a synostosis of the tibia with the fibula will immensely simplify and reduce the extent of the necessary bone-grafting and make bone substitution a more probable success. The use of the fibula in a synostosing operation also may permit use of a leg with a brace, which is still far superior to an amputation for many people.

While unilateral amputation may not be a contra-indication to the amputation of the second extremity, in my opinion it certainly makes the criteria for amputation of the second extremity much more stringent. A bilateral below-the-knee amputee may be very agile, but he is the exception rather than the rule. There are many bilateral above-the-knee amputees who left Service Hospitals on prostheses and canes, with their chins up, who are not using their prostheses at all today, and who are not ambulatory. I believe that a second extremity should not be amputated until the patient is thoroughly convinced that it is a determent to him.

The authors are to be congratulated for pointing out the necessity for careful planning and foresight before starting an extensive program of reconstruction which may take years and accomplish nothing for the patient.

PROCAINE INJECTION FOR RELIEF OF PAIN IN THE HIP

BY WILLARD V. ERGENBRIGHT, M.D., AND FREDERICK C. LOWRY, M.D., IOWA CITY, IOWA

From the Department of Orthopaedic Surgery, State University of Iowa, Iowa City

The control of pain in the arthritic hip has always been a difficult problem for the orthopaedic surgeon. The work of Tavernier and Godinot, Mallet-Guy and de Mourgues, and Ricard and Francillon has demonstrated that pain in the hip can be relieved by surgical section of the obturator nerve and the nerve to the quadratus femoris. The possibility of procaine injection of these nerves was suggested to the authors by Steindler. Landmarks and the technique of injection were worked out on cadavera.

TECHNIQUE

The obturator nerve is injected with the patient in the supine position and the affected extremity in slight abduction, if possible. The pubic tubercle and the femoral artery are palpated; a mark is made at a point halfway between the two, and a thumb's breadth beneath the inguinal ligament. Digital palpation at this point will determine the superior ramus of the pubis. The needle is inserted until it strikes the superior ramus. It is then withdrawn a short distance and tilted so that, as it is reinserted, it passes along the inferior surface of the superior ramus to the obturator foramen. In the majority of cases the patient will complain of pain, radiating along the anteromedial aspect of the thigh. At this point, 10 cubic centimeters of 1 per cent. procaine is injected and the needle is withdrawn.

For injection of the nerve to the quadratus femoris, the patient is placed in the prone position with the involved hip in as much external rotation as possible. The landmarks are indicated with a suitable dye, such as gentian violet. A straight line is drawn from the lower end of the sacrum to the posterior superior spine of the ilium. A point is marked at the junction of the lower and middle thirds of this line. Another point is marked on the lateral surface of the buttock, about one inch posterior to the greater trochanter and on a level with the lower end of the sacrum. A wheal is made at this site, and a long, dull needle is inserted. The needle is directed toward the point indicated on the line between the tip of the sacrum and the posterior superior spine and, as it is inserted, it is tilted to form an angle of approximately 45 degrees with the table (Fig. 1). The insertion is continued until the needle strikes bone. If it has been directed properly, the tip will be against the posterior surface of the body of the ischium, just lateral to the sciatic nerve. The dull point of the needle is then carefully "worked" medially along the bone for another 1 or 2 centimeters.

FIG. 1

During injection of the posterior nerve supply to the hip, the needle is inserted at an angle of 45 degrees with the table.

Frequently this will reproduce the hip pain. Fifteen cubic centimeters of 1 per cent. procaine is then injected slowly. The point of the needle, being against the body of the ischium, allows the procaine to be diffused along the broad, flat surface of this bone, upon which lie the nerve to the quadratus femoris and its articular branches.

RESULTS

Twenty-three patients have been treated by this method. The underlying cause of the hip pain in these patients included osteo-arthritis in eleven cases, congenital subluxation with hypertrophic arthritis in four cases, ununited fracture of the femoral neck in three cases, previous arthroplasty in two cases, congenital dislocation of the hip with an old shelf operation in one case, old Perthes' disease with arthritis in one case, and old, quiescent atrophic arthritis in one case.

Nineteen patients had immediate and complete relief from pain, both when at rest and during motion, after the first injection. Four patients had little or no relief. In two of these four, complete relief from pain followed a second injection, the next day. The other two were discharged from the Hospital before reinjection was attempted. These failures are considered to be due to technical errors.

In addition to loss of pain, eighteen of the patients showed an increase in motion in the involved hip. In several cases there was an immediate decrease in the degree of flexion and of adduction contracture. The improvement in mobility of the hip frequently was associated with disappearance of pain in the lower portion of the back. The five patients who did not gain in motion included the two who failed to obtain relief from pain and three whose lack of increased mobility could be explained on the basis of a mechanical block.

Four patients complained of pain in the knee on the affected side; examination of the knee revealed no local cause for pain. One of these patients had an ununited fracture of the femoral neck; the others had osteo-arthritis of the hip. The pain in the knee was considered to be referred in nature, originating in the hip. Each of these patients experienced relief of pain in the knee as well as in the hip following procaine injection.

The duration of relief from pain following a single procaine injection varied from thirty-six hours to three months; the period of relief apparently had no relationship to the severity of the symptoms.

DISCUSSION

It is the authors' impression that the increased motion of the hip and the diminution of the flexion-adduction contracture following procaine injection are due to relief from pain and to release of reflex spasm of the involved muscles. No explanation is offered for the prolonged absence of pain following a simple procaine injection. However, such an experience is not foreign to those who have used procaine injection of the sympathetic ganglia for such painful syndromes as Sudeck's atrophy or causalgia.

Selective nerve injection is a definite and useful addition to the methods now available for the treatment of pain in the hip. It is not claimed that relief from pain is permanent. However, the result is immediate and the pain may be absent for an indefinite period of time. The procedure is simple and harmless, and may be repeated. It is useful in the patient who is a poor operative risk, and in those for whom arthroplasty or arthrodesis is undesirable. It may also be used as a therapeutic test before surgical denervation of the hip.

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ELECTROMYOGRAPHY IN ORTHOPAEDICS*†

BY ARTHUR L. WATKINS, M.D., BOSTON, MASSACHUSETTS

From the Department of Medicine, Harvard Medical School, and the Department of Physical Medicine, Massachusetts General Hospital, Boston

The orthopaedic surgeon is regularly confronted with the problem of evaluating disorders of neuromuscular function. Although locomotion, strength, and skill can be tested fairly adequately for clinical purposes without elaborate apparatus, there are many cases in which diagnosis and prognosis can be ascertained with greater accuracy if muscular activity is analyzed in a more detailed manner. Electromyography has now been developed to a point where conclusions can be drawn as to its usefulness to the orthopaedic surgeon in the better understanding of some of the complexities of neuromuscular disease.

CONDITIONS IN WHICH ELECTROMYOGRAPHY IS OF VALUE

Poliomyelitis

Considerable interest exists as to the nature of muscle hyperirritability or "spasm" in acute and convalescent poliomyelitis. The clinical features are well known, but for their explanation investigators have turned to the electromyographic laboratory. Numerous reports from widely separated clinics have indicated the presence, in patients with acute poliomyelitis, of abnormal electrical activity in muscles at rest (Fig. 1), whether they have normal strength or are weakened [4, 21, 24, 31]. The completely paralyzed muscles, on the other hand, are electrically silent, with exceptions to be noted later. Change in position or passive stretching has been found to produce strong discharges from the muscles in spasm, corresponding to the clinical findings of pain and tenderness. This type of electromyographic tracing resembles that recorded from muscles splinting a painful joint, secondary to fracture. We cannot say, however, whether or not the mechanism is the same or even similar, as the electromyogram gives information only as to the amount and character of peripheral activity. What is occurring in the central nervous system must as yet be left to conjecture.

Some of the hypotheses which have been suggested are:

1. The disease, which frequently involves the dorsal root ganglion, may incite sensory discharges which, in turn, cause reflex muscle spasm in the corresponding segment.

2. Irritation of the anterior horn cells themselves may produce hyperactivity of the corresponding motor units.

3. Disease of the internuncial neurons may decrease normal inhibitory spinal-cord activity, thus allowing hyperactivity of the lower motor neurons [17]. It has been impossible so far to perform the crucial experiments clinically, to differentiate these possible mechanisms or others which may be acting.

After the acute stage of the disease, when the signs of meningeal irritation have disappeared, much of this electrical hyperirritability also becomes diminished or is absent. Even muscles that are tender to pressure show little abnormality electrically, except for those which are only partially paralyzed. In this case a different type of electromyogram is usually observed. A resting muscle in the position of maximum relaxation shows spontaneous high-voltage, low-frequency discharges which are only slightly increased by stretching (Fig. 2). The same muscles, on attempts at voluntary motion, discharge action potentials of relatively low frequency and irregular low voltage. Their appearance is similar to the discharges recorded from muscles partially innervated from peripheral-nerve injuries, particularly during the stage of regeneration of nerves (Fig. 4). This type of

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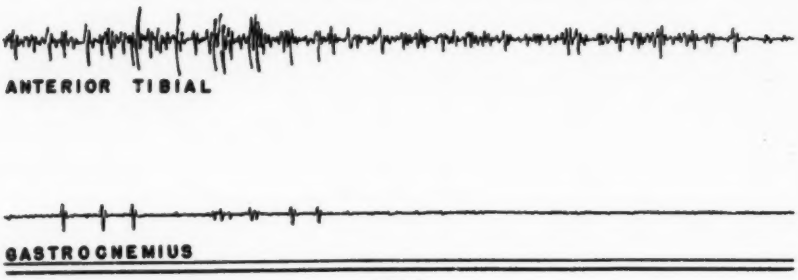

FIG. 1

Passive plantar flexion in acute poliomyelitis. Showing hyperirritability after passive stretching.

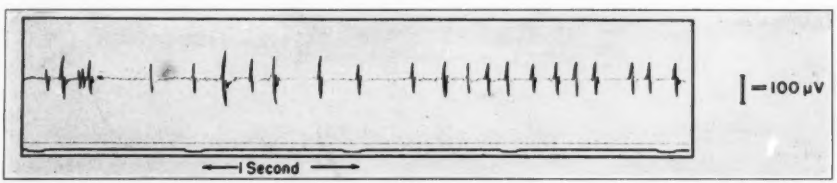

FIG. 2

Partially weakened muscle with impaired innervation. Spontaneous electrical discharges in resting muscles are an indication of the survival of partially functioning nerve fibers in acute poliomyelitis.

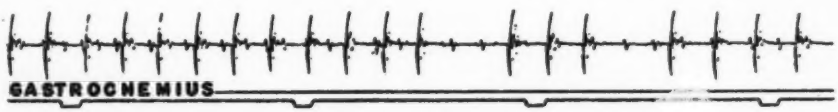

FIG. 3

Spontaneous discharges from resting paretic muscles during stage of increasing strength.

discharge has been recorded months or years after the onset of the disease, and is generally correlated clinically with a state of improving muscle strength (Fig. 3).

A further type of spontaneous discharge from resting muscles is quite different. These potentials are of extremely low voltage and short duration, with irregular and inconstant frequency. Their appearance is that of fibrillation, recorded from denervated muscles in the case of a severed peripheral nerve [13]. This type of fibrillation cannot be recorded satisfactorily with ink-writing electromyographs, the cathode-ray oscilloscope and photographic film being more suited for this purpose (Fig. 5).

Electromyography has demonstrated a further type of neuromuscular disorder in patients with poliomyelitis. This is the co-contraction of muscles of antagonistic function during attempts at voluntary motion [29] (Fig. 6). This is a type of incoordination or substitution which may disappear with training in muscle re-education. It may represent some synaptic dysfunction in the spinal cord, or simply be a poorly organized attempt to produce motion from many muscle groups when there is a considerable degree of weakness.

Electromyograms may also be used as a rough quantitative measurement of voluntary power during active contraction of muscle [23]. There is a correlation between muscle strength and the voltage of action potentials, although it probably is not so trustworthy a quantitative measurement as an ergogram. Because of this approximate quantitative measurement which is possible, electromyography has been used to evaluate the effectiveness of various physical agents on the degree of muscle spasm in poliomyelitis. Results to date, however, have been negative, there being no strong preference for any of the physical agents commonly used, including intramuscular prostigmine [30].

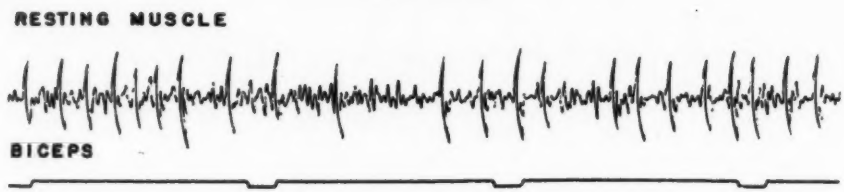

FIG. 4

Fig. 4: Discharges from resting muscles during early reinnervation after injury to brachial plexus.

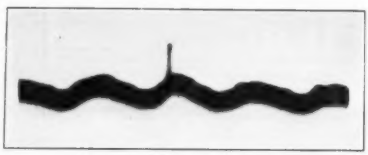

Fig. 5: Fibrillation of denervation in relaxed paralyzed muscle. Total length of record is $\frac{1}{10}$ second; height of potential is 50 microvolts.

FIG. 5

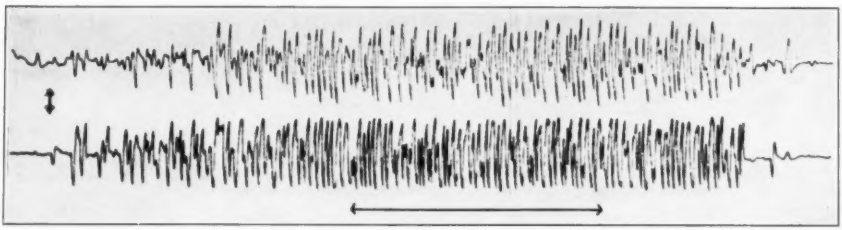

FIG. 6

Co-contraction of paretic muscles with antagonistic action during voluntary flexion of elbow. Upper record is of biceps, lower record of triceps. Calibration: horizontal arrow, 1 second; vertical arrow, 50 microvolts.

It is concluded that in poliomyelitis: (1) electromyography gives a rough quantitative measurement of muscle spasm and strength; (2) disorders of normal reciprocal innervation can be detected; (3) high-voltage, spontaneous discharges at rest are consistent with a favorable prognosis for improvement [28]; and (4) fibrillation denervation potentials are a poor prognostic sign [13].

Peripheral-Nerve Injuries

Electromyography has been used extensively in the study of peripheral-nerve injuries during the past ten years. It has been found possible by this method to detect early signs of reinnervation before there is clinical evidence of regeneration; and to determine the extent of nerve damage, particularly in cases of compression or stretch injuries, where the presence of action potential indicates that the lesion is not complete [6, 20, 27]. It is also useful where there is suspected hysteria or malingering, as normal potentials may be discharged from a muscle which is apparently paralyzed. The greatest value of electromyography is probably in following the course of regeneration of peripheral nerves to determine the extent of reinnervation of muscles.

Ruptured Intervertebral Discs

In patients with pain in the upper extremity and suspected protrusion or rupture of a cervical intervertebral disc, electromyograms have shown the presence of discharges from resting muscles, presumably from irritation of cervical roots [3]. In the case of disc lesions, these discharges are often increased with movements of the neck. By reference to the common root supplying the muscles from which this abnormal activity is recorded, the electromyogram has been found an aid in localization of the lesion (Fig. 7). Similar

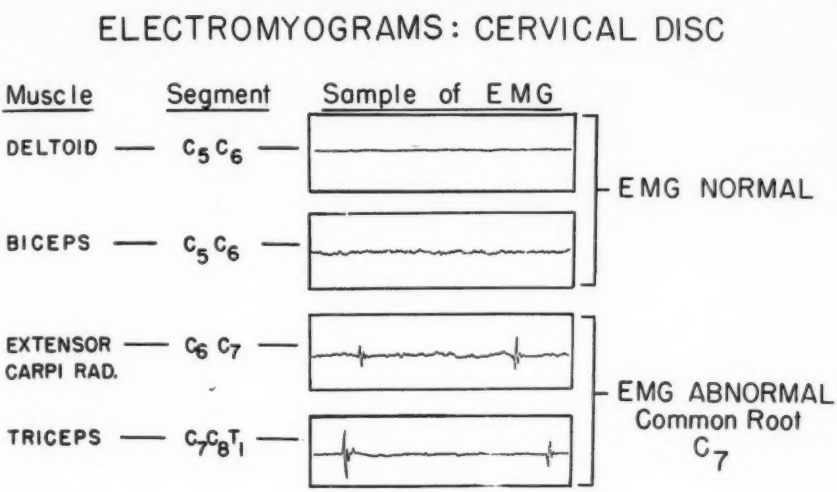

FIG. 7

Spontaneous discharges from resting muscles of patient with proved protrusion of intervertebral disc.

electromyographic tracings can be obtained from patients with lumbar intervertebral-disc lesions. The tracing, of course, does not give a specific diagnosis of disc lesion, but simply suggests irritation of one of the lumbosacral roots. Because of the overlap of segmental innervation of the muscles of the leg, the electromyogram is of less value in localizing the level of the lesion.

Progressive Muscle Atrophy and Amyotrophic Lateral Sclerosis

In these progressive degenerative diseases of anterior horn cells, the electromyogram shows a very characteristic abnormality (Fig. 8). Spontaneous discharges in these conditions produce diphasic spikes of very irregular voltage and frequency. They are often

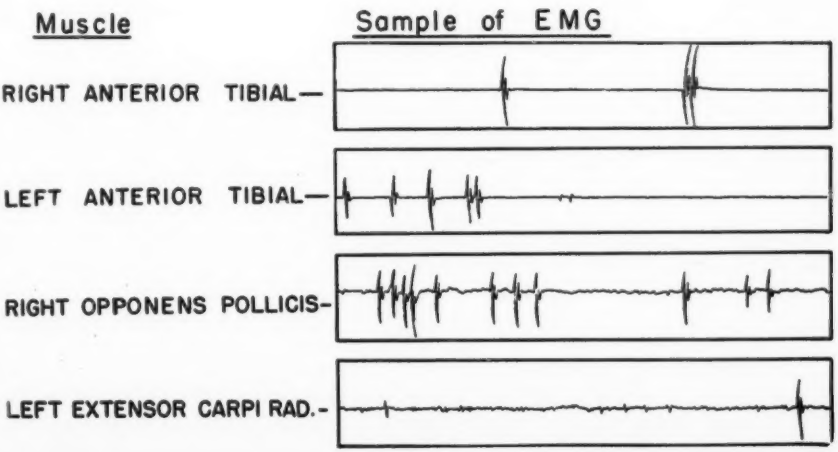

FIG. 8

Resting muscles. Note irregular frequency, voltage, and widespread distribution of potentials in progressive muscle atrophy.

picked up from muscles free of visible fasciculations, so that a general diffuse degenerative disease may be detected at an early stage, when clinical signs reveal only localized muscle atrophy. The amount of electrical activity is also correlated to some extent with the rapidity of progress of the disease process.

Parkinson's Disease (Paralysis Agitans)

Electrical recording of the tremor characteristic of Parkinson's disease is so constant that the electromyogram is of diagnostic importance[22]. There are found to be alternate

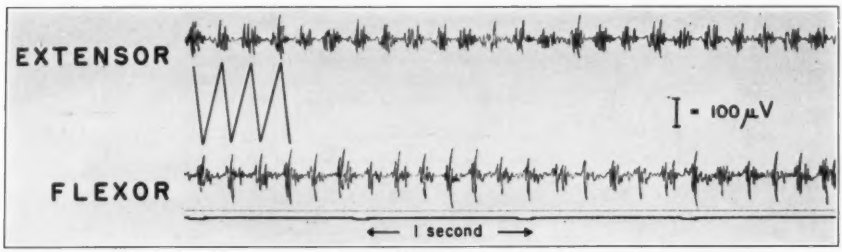

FIG. 9

Parkinson's disease. Showing rhythmically alternating bursts of action potentials.

discharges from antagonistic muscle groups with a regular frequency of about six per second, the bursts of electrical activity having a fairly normal appearance as to frequency and voltage (Fig. 9). As this type of tremor can rarely be reproduced voluntarily, it is possible to differentiate such tremor from that of hysterical origin.

Spasmodic Torticollis

Patients with spasmodic torticollis show diffuse high-voltage discharges from the muscles involved, as would be suspected from clinical examination. The amount of electrical activity may be used to evaluate the effectiveness of various therapeutic agents, such as drugs or locally injected chemicals.

CONDITIONS IN WHICH ELECTROMYOGRAPHY IS OF LITTLE OR NO VALUE

Muscle Dystrophy

There is no characteristic abnormality of the electromyogram in muscle dystrophy. No fibrillation potentials are recorded, there simply being a gradual decrease in the amount of voltage discharged during voluntary action. The completely paralyzed muscles are electrically silent.

Myasthenia Gravis

Although the fatigue characteristic of myasthenia gravis can be demonstrated by means of electromyography, the records do not have an appearance which is specific for this disease, so that it is not an important diagnostic tool.

Spasticity

The hyperactivity of the stretch reflex in patients with cerebral palsy, hemiplegia, and spinal-cord disease can be demonstrated electromyographically by passive stretching. Such electromyograms, however, simply confirm a condition which is obvious upon clinical examination. The degree of spasticity present can be roughly determined quantitatively for purposes of evaluation of therapeutic agents; but this is not exact quantitation, as the electromyogram simply records a small sample of muscle activity,—namely, the muscle

fibers in the proximity of the recording electrodes[18]. It is also impossible to get a quantitative picture of the spasm present in the muscles supporting the hip joint, because of their distance from the skin. Although needles may be inserted into some of these muscles, the sample obtained is a very small portion of the large muscle mass present.

RESEARCH

As electromyographic equipment is expensive and, until recently, was not available on a commercial basis, it has been used largely in research laboratories. Abundant literature on the subject, however, has accumulated, and a few examples related to orthopaedic conditions will be cited. Seyffarth, Lundervold, and Jasper have studied the behavior of motor units in healthy and paretic muscles, particularly in poliomyelitis. Recordings made during well-coordinated movements in normal individuals are also of interest, particularly analyses of the action of individual muscles during voluntary movement of the shoulder and hip[2, 14, 15, 26, 32, 34]. Muscle activity after transposition of the tendon in cases of poliomyelitis has also been the subject of investigation by Weiss and Brown. Spasticity, rigidity, and involuntary movements have been examined extensively, and electromyography has been used to determine the effect of various new drugs for control of this abnormal motor activity[1, 5, 9–12]. One of the most recent techniques devised for clinical use is that related to transmission of the nerve impulse to muscle, by Harvey and Masland, and Hodes and his associates. This opens up a large avenue for further research, which should help elucidate still unsolved problems of neuromuscular dysfunction.

SUMMARY

1. Electromyography has been found useful in studying the pattern of motor activity in normal and paretic muscles, particularly in poliomyelitis and peripheral-nerve injuries.

2. Degrees of spasticity, rigidity, and tremor may be measured semi-quantitatively by this method.

3. Information of diagnostic importance is obtained from patients with progressive muscle atrophy, Parkinson's disease, peripheral-nerve injuries, and hysteria.

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DISCUSSION

Dr. J. E. Markee, Durham, North Carolina: It is a privilege and pleasure to comment on this fine paper. Discussors with clinical experience should elaborate on the usefulness of electromyography as a means of determining whether certain muscles or portions of muscles are contracting or in spasm. Dr. Watkins and other students of electromyography should be encouraged to extend the scope of the study of muscle potentials as a technique of delineating an area that is contracting. Our experimental studies are of interest in this connection only because they indicate that the area from which a muscle potential arises coincides with the area of actual shortening.

Certain theoretical considerations which have arisen in our work with muscle potentials in exposed muscles of the dog may be of interest in a discussion of investigations of this type. Our evidence indicates that the strength of summated muscle potentials is proportional to the number of neuromuscular units which are contracting. The strength of the muscle potential is also proportional to the nerve potential, at least in the

experiments involving isolated muscle twitches in a restricted number of exposed muscle fibers. On the other hand, the muscle potential is not proportional to either the work accomplished, or the tension that is developed, except in so far as the number of units is involved.

By measurement, the muscle potential from a given number of contracting units was not increased, even though the amount of work accomplished was experimentally increased tenfold. Likewise, as long as the number of contracting units was unchanged, there was no appreciable change in the muscle potential, even though the amount of tension developed by these contracting fibers was changed tenfold or even twentyfold. That is, in our experiments, a given number of fibers had about the same potential, first, when they were already short and could produce little tension and, second, when they were partially stretched and capable of producing much greater active tension. Our evidence indicates that the summated muscle potential is a measure of the number of units contracting.

If our experiments can be extended and confirmed, it may be necessary to conclude that the strength of the muscle potential is only a measure of the number of units contracting. On the other hand, manual or ergographic testing supplies information about the efficiency of the contraction, and is not necessarily a measure of the number of units contracting.

If these theoretical considerations can be proved and extended to the human, it should be possible to acquire more useful information about some patients and to improve the care of patients with certain muscle ailments. For example, it might be possible to apply this information to the understanding and care of patients with poliomyelitis. If the muscle potential is purely a measure of the number of units contracting, it should follow that a measurable summated potential from a given muscle would increase throughout convalescence only as long as additional neuromuscular units are recovering. Thereafter, there should be no increase in the intensity of the summated muscle potential, even though the strength of the muscle is increasing as measured by muscle strength, manual testing, or ergographic testing.

If these assumptions are true, the summated potential from a muscle should also give a measure of the number of contracting units in Parkinson's disease and in a number of the other pathological states mentioned by Dr. Watkins. Obviously, adequate apparatus is wanting for most studies of this type.

Much additional information can be made available in the preoperative and postoperative study of muscles, if further studies confirm our evidence that the strength of the potential arising from a muscle is purely a measure of the number of units that are acting. Time limits even the listing of the possible applications to patient care. These possibilities can be explored only through cooperative investigations in the clinics and experimental laboratories.

DR. R. PLATO SCHWARTZ, ROCHESTER, NEW YORK: In this as in many other subjects, one's interest can exceed understanding. However, because of personal interest in the application of electromyography to the behavior of the neuromuscular mechanism, I am grateful for the privilege of discussing Dr. Watkins' paper. He has provided evidence which reaffirms previous observations. This is an important contribution, because the relationship between electromyography and orthopaedic surgery is still young. Many more such observations will be needed before the resulting values become generally accepted.

Dr. Watkins has made new and interesting observations. It is hoped that these will be confirmed by others who are equally capable in this field of investigation. Some comments on the illustrations which he presented are as follows*:

Figure 2, showing a record of spontaneous motor activity in poliomyelitis, confirms previous observations. A higher degree of irregularity in timing and in excursion is commonly observed in such records. Also, the output of 50 microvolts is noted as low in the wide range of 0 to 5,000.

Figure 1, a passive stretch record, is typical of previous observations. The record appears to have been made with a pen motor. There is good separation between the high and low peaks, but the magnitude of I = 50 microvolts strongly suggests that the recording system may have been overloaded. We also noted a series of equally spaced deflections, which we have observed when the pen motor was not following the impulses from the muscle, but was following those frequency components close to its resonance frequency. Therefore, the record revealed the resonance frequency of the pen motor rather than the variable frequency of the muscle impulses.

Essentially the same interpretation can be made of Figure 3. The calibration of I = 100 microvolts should not have a significant influence. In our experience, both 100 microvolts and 50 microvolts are rather low calibrations for the recording of a strong stretch reflex.

Figure 4 is the spontaneous discharge in a resting muscle in association with a fractured elbow. This record shows successive groups of deflections of essentially equal variation in amplitude and uniformity of spacing. Here we may again be observing the characteristics of a record produced by a pen motor, when the pen responds to frequencies approaching its own resonance frequency. Since time and calibration data were not included in the illustration, however, it is not possible to evaluate this record on that basis.

* The illustrations as published are not in all cases those discussed by Dr. Schwartz; although similar, the calibrations differ. Figure 4, mentioned by Dr. Schwartz, has been omitted; Figure 5 corresponds to Figure 4 in the published article.

Figure 5 shows the spontaneous activity of resting muscle in association with a brachial-plexus injury. This record seems to be exactly as described in Dr. Watkins' paper,—that is, similar to records frequently obtained from resting muscles in the acute stage of infantile paralysis.

Figure 6, of poliomyelitis, is typical of the type of response which we have frequently observed in records made on patients in the acute stage of infantile paralysis. However, the record presented is slightly confusing for the want of data. The relationship of voluntary flexion and extension to the tibialis anterior and gastrocnemius was not indicated. However, the principle is clear: The voluntary contraction of the agonist sets up a simultaneous counter contraction in the antagonist.

Figures 7 and 8 are electomyograms of the cervical disc and of amyotrophic lateral sclerosis. We have not made electromyograms of patients with either of these diagnoses; for this reason we have no specific comments regarding these records.

Figure 9. The characteristics of this record of Parkinson's disease reveal a classical pattern which can be duplicated by records taken from our own files. In many instances we have noted that our step-down pattern and the flat baseline are both distorted by other impulses from the muscle, superimposed on those which provoke the tremor. These superimposed impulses have been associated with clinical evidence of rigidity, which is frequently noted in this disease. It is, therefore, important to differentiate between the simple Parkinsonian tremor and the recorded characteristic of this tremor plus rigidity. This is not too difficult, because in either case the timing of the bursts associated with the tremor remains essentially constant.

This lack of information can be summed up in the statement that there are insufficient data to permit other laboratories to attempt to duplicate these results.

Statements are made by Dr. Watkins regarding the possibility of roughly quantitating muscle strength through the measurement of electromyograms. While this statement is categorically true, it must be recognized that several factors can create a degree of "roughness" so large as to make any quantitative expression useless. In Figure 1, which has previously been mentioned, the high spikes and general pattern of the deflections suggest the same type of difficulty we have experienced when calibrating at 300 microvolts per centimeter. The high spikes shown in this record are almost certainly records of pen-motor overswing and would, therefore, bear no relationship to the magnitude of the associated muscle impulses. There is also evidence of pen-motor resonance.

On the positive side, three statements can be made regarding the illustrations presented in this paper. These are common to similar papers from other sources, and are as follows:

1. Electromyograms are capable of revealing the presence or absence of muscle activity in normal and pathological conditions.

2. Discrimination can be made between continuous muscle activity, voluntary or involuntary, as shown in Figures 3 and 9, respectively. In general, it is not possible to distinguish between voluntary and involuntary impulses when they form a continuous pattern, such as that shown in Figure 6. Voluntary and involuntary records are shown on the same chart, and there is nothing to distinguish them. In the case of tremors, however, such as that shown in Figure 9, it is generally accepted that involuntary impulses produce a uniform sequence that is impossible to duplicate intentionally.

3. Under carefully controlled conditions, with known interelectrode distances, constant electrode size, and a calibration level sufficiently high to preclude the possibility of overloading the amplifiers, and at frequencies which do not provoke resonance in the pen, correlation is possible between the amplitude of the electromyogram and the strength of the muscle producing the impulse. This has been found, however, to be more reliable at the lower levels of activity. It is, of course, necessary to change the calibration value in proportion to the amount of effort exerted.

These statements are based upon similar limitations which we have noted in the course of our own efforts to correlate the characteristics of electromyograms with the clinical evidence of abnormal muscle function. Such efforts will probably be continued by us and by others. From these combined experiences will come a definition of principles as related to instrumentation, technique, and interpretation of electromyograms in orthopaedic surgery. For these reasons we should be grateful to Dr. Watkins and should encourage continuation of his work.

DR. ARTHUR L. WATKINS (closing): I should like to thank the discussors for their enlightening remarks concerning the work done on electromyography in their laboratories. Dr. Schwartz has raised the question of overloading of the recording pen. We have not been using, I believe, a pen motor of the type Dr. Schwartz has tested. In any case, our recording system has been tested specifically for overloading. Using monophasic 2-millisecond impulses, no overswing occurred with an input overload of ten times; this also held true with diphasic impulses. Tests were performed with increasing power and frequency. Again no overshooting was observed with frequencies from 50 to 150 cycles per second. No problem of pen resonance was encountered in this frequency range.

HEMANGIOMA OF THE KNEE JOINT

BY JULIAN E. JACOBS, M.D., AND F. WAYNE LEE, M.D.*, CHARLOTTE, NORTH CAROLINA

From the Department of Orthopaedic Surgery, Charlotte Memorial Hospital

Although hemangioma of the knee is rare, it is deserving of attention by the orthopaedic surgeon, because of the challenge which it presents in differential diagnosis. Approximately thirty authentic cases of this entity have been reported in the literature; of this number, less than five were diagnosed correctly prior to arthrotomy. With a better understanding of the clinical picture as related to the underlying pathological condition, the percentage of correct diagnosis before surgery can probably be increased greatly.

This paper presents two cases of cavernous hemangioma of the knee joint.

CASE 1. P. H., a white male, aged seventeen, was first admitted to the Hospital on January 22, 1944. An initial attack of pain and swelling had followed immediately after injury to the right knee, eight years previously; but the symptoms had subsided spontaneously in a few days and joint function was completely restored. During the intervening years, similar episodes had occurred, with or without minor injury; there had never been evidence of inflammatory involvement. The knee had been treated by his local doctors and by specialists in a large eastern city. Because of the recurrent nature of the disease and the increasing severity of the attacks, hospitalization had been advised.

At the time of examination, the right knee joint was distended by a moderate amount of fluid. The muscle atrophy at the thigh was minimal, and the joint could be carried through a normal range of motion except that the extremes of flexion and extension caused some discomfort. The skin overlying the joint was entirely normal, and the inguinal glands were free of involvement.

Roentgenograms revealed a small, ill-defined area of increased density within the anterior compartment of the joint. This was seen best in the lateral view, with the knee flexed about 10 degrees beyond a right angle.

Because of the involvement of a single joint, the chronicity of the process, and the progressive nature of the disease, an arthrotomy was performed. After the capsule had been entered through a medial parapatellar incision, it was noted that the synovial membrane had been invaded and distended by a bluish lobulated mass, which was attached to the membrane at the postero-inferior margin of the patella. This tissue was extirpated with little difficulty, hemorrhage not presenting a problem to the operator. The pathologist reported a cavernous hemangioma of the knee joint.

The patient's extremity was immobilized in plaster for two weeks after operation and, aside from a slight amount of effusion, the knee recovered without incident. After a period of active physical therapy, joint function was completely restored.

Six weeks following discharge from the Hospital, the patient returned for a series of deep roentgen treatments; he received a total of 1,200 r through two portals. More than four years have elapsed since the operation, and this patient is entirely free of symptoms. He is very active in athletics and describes the knee as normal.

CASE 2. M. P., a white woman, aged thirty-five, was admitted to Charlotte Memorial Hospital on December 31, 1945. She had injured her left knee twenty years previously, while skating. Attacks of pain and swelling had recurred intermittently since the injury, and had been most frequent during the six to eight months preceding admission.

Examination showed that the swelling was more prominent in the medial compartment of the knee; a small granular mass could be palpated in this area, overlying the medial femoral condyle. Slight tenderness was present; the inguinal glands were not affected. Measurement of the thigh failed to reveal atrophy, and the overlying skin was normal. Roentgenograms of the knee were essentially normal.

After three months of conservative therapy, an arthrotomy was performed through a lateral parapatellar incision. A blue cystlike mass was encountered in the capsule; this was dissected free and excised *in toto*. The pathologist's report was: "Benign hemangioma of knee joint, partially telangiectatic and partially cavernous in type." The articular structures were not disturbed by the process. The patient had a smooth postoperative course and was discharged from the Hospital one week after the arthrotomy. She received intensive physical therapy for approximately two weeks, and was discharged with almost complete restoration of knee motion. Two and one-half years after operation the patient reported normal function of the knee.

* Fellow of the National Foundation for Infantile Paralysis, Duke Hospital, Durham, North Carolina.

DISCUSSION

Articular hemangiomata may be either juxta-articular or intra-articular. An intermediary type, which involves both the interarticular and periarticular structures, may be added to the classification. In the juxta-articular type the process involves the periarticular structures, particularly the quadriceps muscle, and the tumor is always palpable. This type is characterized by the absence of involvement of the capsule and synovial membrane and, therefore, presents a clinical picture quite different from the intra-articular variety.

The intra-articular type is demonstrated by the two cases presented. The process may occupy any part of the synovial cavity, and the anterior fat pad may be completely replaced. The tumor is capable of causing destruction by pressure atrophy, and one case has been reported in which deep erosions in the cartilage and underlying bone were encountered. This presents a difficult problem in treatment.

Histologically, the articular hemangiomata have been classified as cavernous, capillary, and telangiectatic. Excessive fat tissue or small zones of chronic inflammatory reaction may be seen. These lesions are probably not true tumors, but rather hemartomata. They are congenital malformations of circumscribed vascular tissue, and, as such, show no capillary budding (Figs. 1-A and 1-B). The sections show a system of sinusoids in which the spaces are lined by endothelial cells. The remaining wall is made up of collaginous connective tissue. There is no evidence of thrombosis; this feature is of importance in considering diagnostic characteristics.

As mentioned previously, articular hemangiomata are usually not suspected before operation. The impressions most commonly mentioned are lesions of the menisci, loose bodies, or articular tumors, without specification of the type. In the first case presented, the initial impression was that of internal derangement, a second impression of synovitis being mentioned. In the second case the diagnosis was tumor, type undetermined.

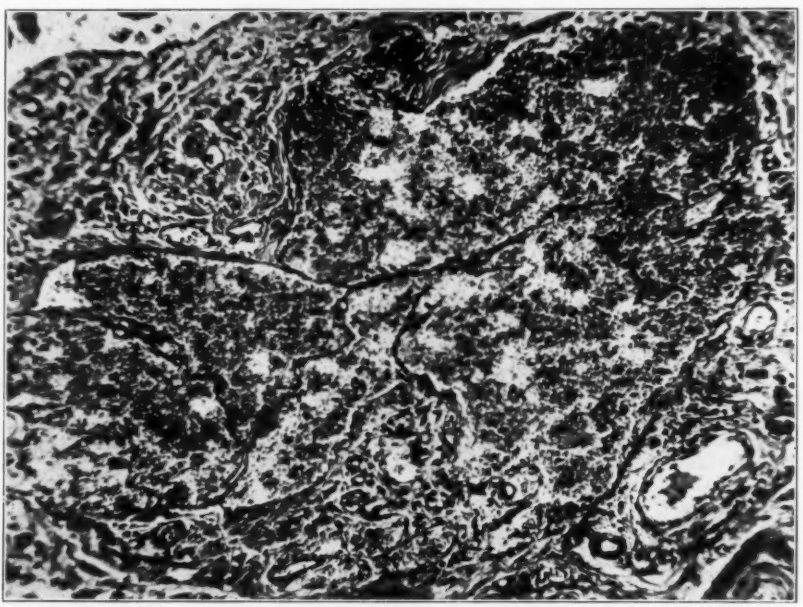

FIG. 1-A

(S-40-46). Low-power magnification showing telangiectatic portion of hemangioma. The lumen is filled with blood; the walls, extremely thin, are composed of a single lining of endothelial cells and a very delicate, thin layer of connective tissue.

Clinically, the first symptom in these cases is pain, often appearing after trauma. The trauma apparently causes hemorrhage from the hemangioma, either by direct con-

FIG. 1-B

Cavernous portion of hemangioma with thick-walled sinusoids, most of them filled with blood.

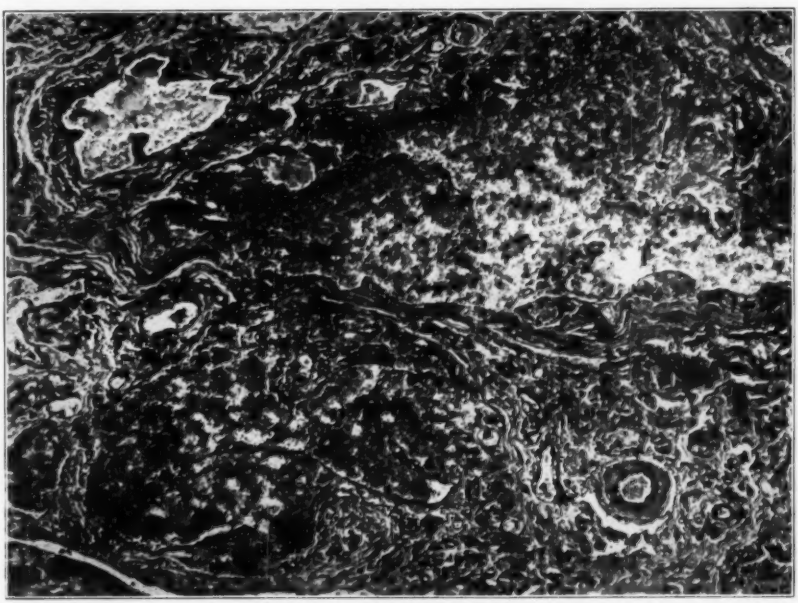

FIG. 1-C

Shows portions of both cavernous and telangiectatic capillary hemangioma.

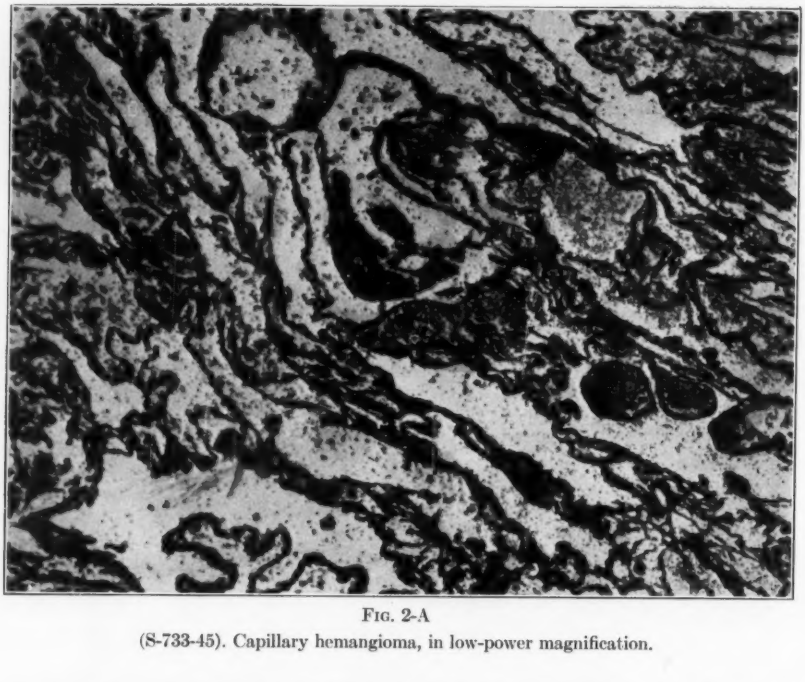

FIG. 2-A

(S-733-45). Capillary hemangioma, in low-power magnification.

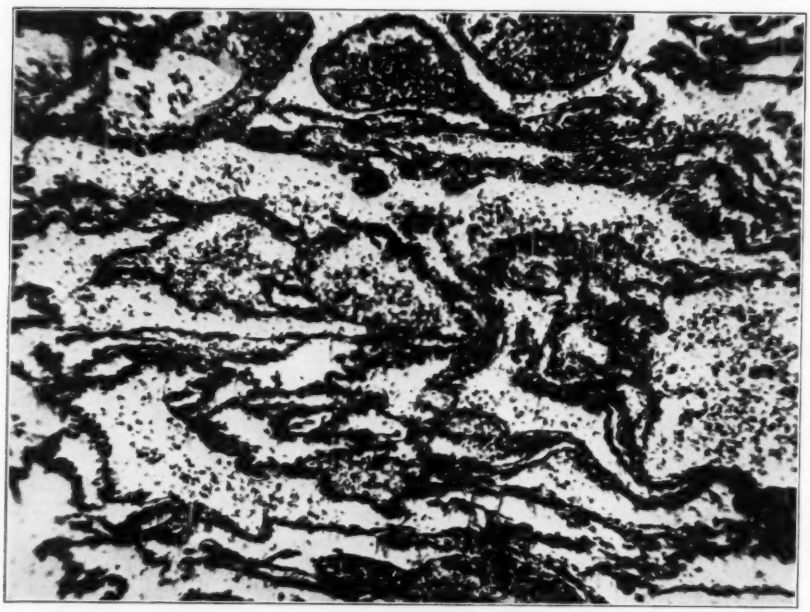

FIG. 2-B

Capillary hemangioma, under high-power magnification, showing the distended capillaries and thin-walled sinusoids filled with blood.

tusion or by pinching between the articular surfaces. Serous or serosanguineous effusions are frequently encountered in the course of these lesions, such a phenomenon being readily explained by the fragility of the vascular walls which make up the structure. Both pain and swelling may appear at long intervals, accompanied by partial loss of joint motion. Blocking and buckling, either alone or in combination, have not been observed. Atrophy or hypotonia of the muscles of the thigh may be seen. From these signs and symptoms it would obviously be difficult to arrive at a diagnosis of hemangioma. If hemarthrosis develops, two more possibilities are immediately suggested,—namely, hemophilia and hemorrhagic arthritis.

When cutaneous angioma coexists, articular involvement is strongly suggested. These masses of tissue do not show pulsation or rhythmic expansion; if this is observed, a diagnosis of cirsoid aneurysm should be made. These areas of tissue are very sensitive to pressure and even to mild palpation, thus accounting for the diagnosis of an inflammatory lesion in many cases.

The obvious deformity which accompanies most of the extra-articular hemangiomata is easily recognized. However, the intra-articular variety may develop within the joint cavity, have sufficient space in which to expand, and thus be overlooked on mere inspection. The volume changes which accompany changes in posture are of the utmost importance and, as one can appreciate from the histological picture, there is ample space for distention and collapse of these multiple sinusoids.

The differential diagnosis from hemarthrosis of hemophilia is established by the sex of the patient, the presence of increased coagulation time, and the clinical characteristics of hemophilic arthropathy, which leads to chronic arthritis with restriction of function and finally to ankylosis in flexion. The one condition in which a differential diagnosis may be virtually impossible is hemorrhagic arthritis. The histological appearance of diffuse hemorrhagic synovitis will serve to differentiate these two, yet the clinical appearance may be indistinguishable.

Loose bodies within the joint may also present a problem in differential diagnosis, for in either case the signs and symptoms are compatible with articular derangement.

The roentgenographic examination is rarely helpful in diagnosis, but, as the first case demonstrates, it may be of slight benefit. It is possible to visualize articular angiomata by the use of an opaque material, injected intravenously. It is relatively easy to see the area infiltrated with such a contrast medium, but the shadow will often disappear in about fifteen minutes due to the rapid dilution of the substance in the blood current of the angioma.

Hemangiomata may disappear spontaneously as a result of thrombosis and subsequent scarring, but this cannot be relied upon, particularly about the knee, where repeated traumata are common. The only logical treatment of these lesions is that which is designed to eradicate the mass. Although there are many proponents of treatment with roentgen rays and radium, it seems more reasonable to assume that surgical extirpation is the treatment of choice. Surgery is often necessary to verify the diagnosis.

SUMMARY

Articular hemangiomata can be diagnosed prior to surgery in practically all cases, provided the correlation between the clinical picture and the pathological process is fully appreciated. These signs are significant: (1) the presence of a circumscribed mass, which is covered by normal skin and which increases in size when the extremity is in the dependent position; (2) the presence of blood after puncture of the mass; and (3) the disappearance of the contrast substance roentgenographically after injection into the vascular area. Surgical excision offers excellent end results.

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OSTEOSYNTHESIS OF THE NECK OF THE FEMUR *

BY JOHS. SPOTOFT, M.D., KALUNDBORG, DENMARK

So far, no comprehensive report has been made of the final results of extra-articular osteosynthesis, which was introduced with the Smith-Petersen nail. We consider an observation period of three to four years as essential in order to get reliable impressions about the final results.

The purpose of this work has been to elucidate the value of extra-articular osteosynthesis, the judgment being based upon an analysis of the case histories of a considerable number of patients, and correlation of these findings with a late examination of the survivors. The patients were operated upon in twelve great Danish surgical clinics, prior to 1939. After an observation period of at least three and one-half years, all the survivors—a total of 183—have been re-examined clinically and, except in three cases, roentgenograms in two planes have been taken.

CLASSIFICATION OF THE FRACTURE

For several reasons it is difficult to compare the various statistics concerning fracture of the femoral neck, not least because of the confusion prevailing as to the classification of the fracture. As neither the anatomical classification, Böhler's classification (as valgus fracture and varus fracture), or Pauwels' classification (into three degrees, according to the angle between the fracture plane and the axis of the femur) gives a generally valid impression of a fracture of the neck, the author has found it practical to combine the three classifications. This affords at once an anatomical, pathological, therapeutic, and prognostic impression.

This combined classification is exceedingly simple, namely:

1. True fracture of the femoral neck.
   A. Valgus fracture.
   B. Varus fracture, with consideration of the angle between the fracture plane and the axis of the femur.
2. Pertrochanteric fracture.

* Abstract of monograph written by author in 1944 (see reference). Presented with permission of Ejnar Munksgaard, Copenhagen.

TABLE I

DISTRIBUTION OF FRACTURES

Fracture		No.	Per cent.
True fracture of the femoral neck		329	64
Valgus fracture	51 (15.5%)		
Varus fracture	278 (84.5%)		
Pertrochanteric fracture		183	36
Total		512	100

In calculating Pauwels' angle, it is practical to use roentgenograms taken during the operation, where the femur as a rule is in slight inward rotation, as the angle in question is real only in this position. It cannot be calculated, for instance, on roentgenograms of recent unreduced varus fractures.

From 1934 until 1938, a total of 512 patients with fracture of the neck of the femur were admitted to four surgical departments in Copenhagen. An analysis of all the roentgenograms of these patients, according to the classification set forth, gave the distribution shown in Table I. Therefore, it is safe to say that, of all the fractures in this region, two-thirds are fractures of the neck itself (about one-sixth of these are valgus fractures, while about five-sixths are varus fractures) and one-third are pertrochanteric fractures.

HEALING OF FRACTURE OF THE FEMORAL NECK

Today it is the general view that every fracture of the femoral neck which is reduced ideally and retained in this position for a sufficient length of time will heal by osseous union. In explanation of the poor healing capacity of the neck of the femur, the following causes have been mentioned:

Poor Nutrition of the Head and Neck

The blood supply of the head and neck is subject to wide variation, and undoubtedly the apparently capricious appearance of capital necrosis and delayed healing is in part due to this. The synovial vessels are liable to damage because of the injury to the capsule, and of course this risk increases with the dislocation. Owing to the outward rotation, the vessels of the posterior aspect of the neck have a better chance of remaining unbroken. Even though the vessels are not ruptured by the dislocation, however, they may be stretched, twisted, or compressed so that the blood flow becomes compromised.

It is reasonable to assume, then, that a preliminary reduction of the fracture, as soon after the accident as possible, is essential in order to protect these vessels from further injury. Consequently, the usual confinement of the patient to bed for several days before reduction is inexpedient.

TABLE II

RELATION BETWEEN DEGREE OF DISLOCATION, HEALING, AND NECROSIS OF THE HEAD

Primary Dislocation	No. of Patients	Healing		Capital Necrosis	
		(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)
Marked	78	54	69.2	52	66.7
Slight	100	86	86.0	33	33.3

TABLE III

RELATION BETWEEN NECROSIS OF THE HEAD AND HEALING IN 180 PATIENTS

Degree of Necrosis	No. of Patients	Healing		Pseudarthrosis	
		(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)
Total	59	41	69.5	18	30.5
Partial	26	23	88.5	3	11.5
None	95	84	88.4	11	11.6

TABLE IV

RELATION BETWEEN AGE OF THE PATIENT AND HEALING OF THE FRACTURE

Age of Patients Re-examined	No. of Patients	Healing	
		(*No.*)	(*Per cent.*)
Under 60 years	77	61	79.2
60 years and over	103	80	77.7

That the dislocation and the resulting decrease in nutrition of the head play a considerable role in this respect is evident from the findings in Table II, in which the patients are classified according to the degree of primary dislocation. It will be noticed that the greater the primary dislocation, the greater is the probability of capital necrosis.

Necrosis of the Head

The relation of this phenomenon to the process of healing will be discussed later. Necrosis forms no absolute obstacle to healing, merely delay. Table III illustrates the relation between capital necrosis and healing in 180 patients who were re-examined.

Age of the Patient

Previously, clinicians believed that the age of the patient played an important role in healing. This is not indicated by the present study (Table IV). Age in itself should not be looked upon as a contra-indication for operative treatment.

Of those factors under our control which promote healing of the fracture, only the following are important: quick and gentle reduction in order to avoid additional vascular injuries,—above all, an ideal reduction and a sufficiently long immobilization.

Pauwels' Theories

Fuchsig analyzed forty-one fractures treated by the Whitman method, and his findings coincide with Pauwels' theories. Thus he concluded that eleven of fifteen pseudarthroses belonged to fractures in Pauwels' third-degree class. Opinions differ as to the patients submitted to osteosynthesis. Most investigators, however, find no concordance between the angle of the fracture and osseous healing.

TABLE V

HEALING OF THE FRACTURE IN RELATION TO PAUWELS' CLASSIFICATION

Pauwels' Classification of Fractures	No. of Patients	Healing	
		(*No.*)	(*Per cent.*)
First degree	22	18	81.8
Second degree	110	85	77.3
Third degree	46	37	80.4

The present material has been analyzed with a view to Pauwels' theories. The relation between Pauwels' three groups and the osseous healing in 178 patients is presented in Table V. The healing percentage is about the same for all three groups.

With a special apparatus belonging to the Danish State Testing Laboratory, the author has tried to see whether Pauwels' theories might be confirmed experimentally. In specimens obtained from postmortem material, fractures of the first and third degree were produced, respectively, on the right and left sides of the neck of the femur, after which the fracture fragments were nailed. In the apparatus a weight of 250 kilograms was put on the head, alternating with complete "unloading" (thirty times per minute), corresponding to a slow gait *in vivo*. In all cases the results were consistent, showing that in both forms the fracture site was able to withstand a 40,000-repetition periodic tolerance test with a load of 250 kilograms. With an additional load, the third-degree fractures broke down earlier than the first-degree fractures,—at 330 and 490 kilograms, respectively.

This illustrates the enormous fixation power of the nail, even under mechanically poor conditions. The outcome of the experiments lends support to Pauwels' theories.

Duration of the Healing Process

The period required for healing has been estimated differently by various authors—from two or three months to two or three years—and there can hardly be any doubt that it is subject to wide variation. Furthermore, the estimate is based upon roentgenographic evidence, which is very difficult to judge in this fracture because the periosteal callus is lacking.

A critical review of the roentgenograms presented in various books and papers as demonstrating osseous healing reveals that in many cases this healing is questionable. Many surgeons have suffered disappointment when, trusting the roentgenographic diagnosis of osseous healing, they have extracted the nail and then obtained a fresh dislocation of the fracture.

It is advisable, therefore, to follow the criterion given by Felsenreich: Osseous healing is reliable only when the roentgenogram clearly shows osseous trajectories crossing the fracture gap everywhere and filling it completely.

PLACING OF THE NAIL

In deciding where to place the nail in the neck and head of the femur, two factors should be taken into consideration: (1) the optimum biological conditions for healing and (2) the mechanical aspects of the fracture. The nail has to be placed where it will best meet the requirements of both factors.

From a biological point of view, the question is how to induce the best healing conditions possible. According to Pauwels, these are obtained by elimination of dislocating forces and by the production of functional pressure at the site of the fracture.

From a mechanical point of view, attention must be paid to the following three points:

1. *Firmness of the Cervical and Capital Spongiosa in Various Sections:* Nyström found the firmness of the cervical spongiosa to be greatest postero-inferiorly, while in the head it was greatest in the center. The trochanteric cortex is also strongest posteriorly, where it is reinforced by the osseous trabeculae from the lesser trochanter. It will, therefore, seem most proper to place the nail steeply, a little posteriorly in the neck, and centrally in the head.

2. *Dislocating Power of the Muscles:* It is well known that the outward rotators of the hip joint are very powerful. Subsequently it will be described how this force contributes to redislocation under rotatory cutting by the nail in the head. The more the nail is placed above and anteriorly in the head, the more readily will this complication appear. Therefore, if regard is to be paid to this displacing influence of the muscles, the nail ought to be placed a little inferiorly and posteriorly in the head.

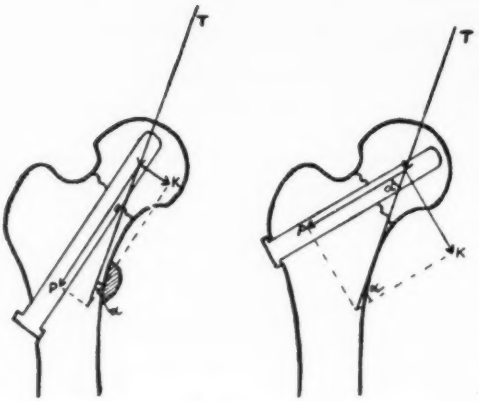

FIG. 1

A comparison of the distribution of forces on the fracture and the nail when the placement of the nail is steep and when it is more horizontal.

3. *Dislocating Forces Arising from the Weight of the Body during Walking:* The forces produced by the weight of the body in walking are stronger than is generally imagined. From the fundamental work on the gait of man, reported by Fischer in 1899, it is evident that, every time the foot is put to the ground during ordinary walking, the head of the femur has to carry a load about four or five times the weight of the body. Knowledge of the enormous forces acting on the head of the femur during walking tends *a priori* to make one hesitate in allowing a patient to bear weight on a limb soon after osteosynthesis has been performed.

Figure 1 illustrates the mutual relations of the forces with a steep placement of the nail and with the prevailing, more horizontal placement. The force, T, that acts on the head of the femur may be divided into P, which is parallel with the nail and has an impacting effect on the fracture, giving a functional pressure at the fracture site; and K, which acts vertically on the nail. It will be noticed that $K = T \sin \alpha$. This means that the steeper the position of the nail, the more functional will be the pressure on the fracture site, and the less the bending force acting upon the nail. With the two angles of the nail demonstrated (Fig. 1)—namely, 140 degrees and 115 degrees with the longitudinal axis of the femur—the difference is so great that the nail placed steeply is able to carry nearly twice as great a weight as is the nail in a more horizontal position.

In addition, owing to friction, the steeply placed nail offers greater resistance to the displacing forces acting on the site of the fracture. Finally, when the nail is placed steeply and the bending force on it thus is reduced, the risk of the nail cutting into the head is lowered.

Thus the steeply placed nail offers the following advantages:

1. The displacing forces at the site of the fracture are diminished.

2. The nail is exposed to less strain as a result of movement and walking, and hence it does not bend or break so readily.

3. Spontaneous impaction is promoted,—primarily by diastasis at the site of the fracture, secondarily by absorption of the neck.

4. The functional (callus-inducing) pressure on the fracture surface is increased.

5. The risk of the nail cutting into the head is reduced.

In contrast to these advantages, only one objection can be made: It is more difficult to drive the nail vertically than horizontally. This, however, is merely a question of technique. With preliminary drilling before the introduction of the wire, as well as before the driving in of the nail, there is no difficulty in placing the wire and nail in a steep position.

Experiments on the Significance of Placement of the Nail

In the State Testing Laboratory at Copenhagen, the author has carried out a number of experiments on femora with recent or old fractures of the neck, removed at autopsy, and on femora of patients who died from other causes. Attempts were made to answer two questions:

TABLE VI

FREQUENCY OF NECROSIS OF THE HEAD

Patients Re-examined	No. of Patients	Total Necrosis of Head (*No.*)	Total Necrosis of Head (*Per cent.*)	Partial Necrosis of Head (*No.*)	Partial Necrosis of Head (*Per cent.*)
Total number	180	59	32.8	26	14.4
With osseous healing	141	36	25.5	22	15.6

TABLE VII

RELATION BETWEEN PRIMARY DISLOCATION AND NECROSIS OF THE HEAD

Primary Dislocation	No. of Patients	Necrosis of Head (*No.*)	Necrosis of Head (*Per cent.*)
Slight	100	33	33.3
Marked	78	52	66.7

1. Are nailed fractures suitable for early weight-bearing? In particular, does the asserted difference in the weight-bearing capacity in Pauwels' three groups hold true?

2. Which placement of the nail is ideal from an entirely mechanical point of view?

The outcome of the first series of experiments has been noted, and the experimental technique has been mentioned briefly. Most of the experiments were carried out as follows: First, weight was applied to the bone directly, with increases of 20 kilograms, up to 240 kilograms; then the experiment was continued with a weight of 250 kilograms, thirty times a minute. If the bone did not give way, this weight was continued for a total of 50,000 repetitions, corresponding to a walk of about ten miles. After this, the addition of weights was continued with increasing pressure until the bone broke down, at the site of the fracture or elsewhere. All experiments were carried out in duplicate, and both femora were removed in every instance so that one acted as control.

The question as to whether the site of an osteosynthesis is suitable for early weight-bearing is very difficult to settle. Numerous clinical experiences have shown plainly that early weight-bearing may give excellent results with osseous healing. Many of the experiments showed also that the "nailed" bones were able to withstand protracted periodic weights of 250 kilograms without any shifting at the site of the fracture. The outcome of these experiments, however, was largely dependent upon the quality of the osteosynthesis.

The difference between the first and the third-degree fractures mentioned by Pauwels was confirmed by these experiments. Depending upon the strength of the bone, the breakdown appeared when weights of 100 to 450 kilograms were added. In all the experiments, however, the first-degree fractures did not break down until the weight was about one and one-half times that under which the third-degree fractures broke down.

Of greater interest are the experiments with Pauwels' third-degree fractures, when the nail is first placed almost horizontally and then more steeply. In eighteen duplicate experiments, the results were all in favor of the steep placement of the nail. A typical example of such an experiment is given:

Both bones were able to withstand 50,000 applications of 250 kilograms of weight without any change in form, but with an impaction which in both cases amounted to 3.5 millimeters. Under subsequent weight additions with increasing pressure, the bone in which the nail had been placed steeply broke down at a pressure of 730 kilograms, whereas, with the more horizontal placement of the nail, the bone broke down at 340 kilograms.

In recapitulating the evidence provided by theoretical considerations, clinical experiences, and practical experiments in proper placement of the nail, the following points should be emphasized:

TABLE VIII

RELATION BETWEEN NECROSIS OF THE HEAD AND AGE OF THE PATIENT

	Under 50 Years	51–60 Years	61–70 Years	Over 70 Years
Number of patients	28	33	53	27
Necrosis of head	12 (42.9%)	13 (39.4%)	24 (45.3%)	9 (33.3%)

TABLE IX

ROENTGENOGRAPHIC RE-EXAMINATION OF 180 PATIENTS

Group	No. of Patients	Per cent.
Healing of the fracture	148	82.2
Pseudarthrosis	32	17.8

1. Subcapital and transcervical fractures should be analyzed according to Pauwels' principles of classification.

2. In first and second-degree fractures, central placement of the nail in the neck and the head is excellent, even though placing of the nail more steeply is better mechanically.

3. In third-degree fractures, the nail ought to be placed steeply, preferably at an angle with the femoral axis of at least 150 degrees.

4. In the horizontal plane the nail should be placed centrally or a little posteriorly in the neck, if the reposition permits. One has to avoid having the nail enter the anterior upper quadrant of the head, because this placement disposes to redislocation through cutting by the nail during rotation.

CAPITAL NECROSIS

In the fractures in the present study—all treated by osteosynthesis—the most frequent late complication has been necrosis of the head of the femur followed by arthrosis, and this is the commonest cause of permanent disablement. In the literature, capital necrosis is not fully dealt with, simply because of its late clinical manifestation, so that the re-examinations reported imply too short a period of observation.

The present material, with an observation period of at least three and one-half years, shows the surprising fact that, among 180 patients who were re-examined roentgenographically, total necrosis of the head was found in about one-third and partial necrosis in nearly one-sixth. Thus the outcome was complicated by capital necrosis in nearly half of the patients (Table VI).

Etiology

Most authors agree that necrosis of the head of the femur belongs to the large group of cases of aseptic bone necrosis of vascular nature. In general, we may expect the extent of capital necrosis to be parallel with the injury to the capsule (Table VII). Among patients with little or no primary dislocation, capital necrosis was found in about one-third, whereas in those with marked primary dislocation, it was found in about two-thirds.

Site and Form of the Fracture

In contrast to what has been asserted by many authors, the site of the fracture plays a minor role in the development of capital necrosis. Among the healed subcapital and transcervical fractures in the present study, capital necrosis has been demonstrated, respectively, in 42.6 per cent. (twenty-three of fifty-four) and in 40.2 per cent. (thirty-five of eighty-seven).

TABLE X

OUTCOME OF CLINICAL RE-EXAMINATION OF 183 PATIENTS

Group	No. of Patients	Per cent.
I. Ideal	50	27.3
II. Good	42	23.0
III. Fair	52	28.4
IV. Poor	39	21.3

Neither does the form of the fracture appear to play any role in this connection. Among the healed fractures of Pauwels' first and second degrees (taken as one group) and those of third degree, capital necrosis had developed, respectively, in 41.7 per cent. (forty-three of 103) and in 40.5 per cent. (fifteen of thirty-seven). Therefore, we may hardly expect any relation between the form and site of the fracture and capital necrosis.

Age of the Patient

Various authors think that capital necrosis is particularly frequent in young persons, probably because the complication gives more conspicuous symptoms in youth. That its frequency probably does not increase with increasing age is evident from Table VIII, in which only healed fractures are reported.

Valgus Position of the Head

There is no foundation for the belief, expressed by Pauwels, that the valgus position is nearly always associated with capital necrosis, owing to the resulting change in the load placed on the head. Among the healed fractures in this study in which the head was in marked valgus position and those in which the head was in nearly normal position, capital necrosis had developed, respectively, in 38.5 per cent. (fifteen of thirty-nine) and in 40 per cent. (sixteen of forty). It is the more fortunate as, to obtain good statics, the valgus position ought to be aimed at during the operation.

Poor Reposition

Felsenreich and Mouchet have emphasized that poor reposition disposes to capital necrosis. In the present study, the figures to this effect are too small to convey any idea about the question. No doubt the fractures associated with marked dislocation are generally accompanied by an extensive tear of the capsule, and for this reason alone they predispose to capital necrosis.

The Nail as a Foreign Body

Before osteosynthesis was adopted, capital necrosis was by no means an unknown phenomenon or particularly rare. Indeed, most authors think that capital necrosis is not due to the presence of the nail as a foreign body, although several believe that the nail, with its broad flanges, tends to compromise the nutrition of the head.

Nyström called attention to the risk involved when the tip of the nail is placed either too near the fovea capitis or in it. In order to get an idea of the risk involved by such placing of the nail, the material has been analyzed with this point in view. Among the fractures in which the tip of the nail was in or near the fovea capitis and those in which the tip was at least 0.5 centimeter from it, capital necrosis appeared, respectively, in 56.4 per cent. (twenty-two of thirty-nine) and in 35.3 per cent. (thirty-six of 102). Even though the figures furnish no conclusive proof, they indicate that the vicinity of the fovea should be avoided during operation.

The Metal

Several authors hold that the metal plays an important part in the appearance of capital necrosis. I think it depends largely upon the character of the steel, but in this study capital necrosis is nearly three times more frequent in cases with roentgenographic evidence of nail osteitis as in cases without nail osteitis (respectively, thirty-five of seventy-nine and six of thirty-six). Therefore, the physician must be very careful in his choice of nail material. To be on the safe side, he should use V2A steel or Vitallium.

From the deliberations concerning the etiology of capital necrosis, the conclusion must be drawn that avascularity of the head is the most important factor. There are probably only two other contributory factors,—poor nail material and poor placement of the nail.

Diagnosis

Once the subjective symptoms of pain, limp, and limitation of motion have appeared, it is easy to make the diagnosis. Roentgenograms show spotted configuration in the head and, often at this stage, infraction and possibly beginning arthrosis.

Treatment

Since capital necrosis begins with softening of the head from about the fifth month to the commencement of the third year, the only rational treatment is to free the extremity from too much strain until the head again has become firm. In 1930, Phemister showed that infraction may be avoided by elimination of weight-bearing for a sufficient length of time.

In determining the thoroughness of this sparing of the hip, it is reasonable to take into account the age of the patient, his weight, mental habitus, and social status. In most cases it will be sufficient to employ merely one cane, if it is used effectively, to spare the hip a great deal of strain. Complete elimination of weight-bearing is a severe trial, mentally as well as physically, in old and feeble persons; in dealing with younger persons, it is only rational to make the demand more categorical, considering that such a "quarantine" for a year and a half probably will save them from permanent disablement.

In the present study it has been found that, in capital necrosis without avoidance of weight-bearing, the chance of infraction is 75 per cent. If infraction has taken place, the prospect of a satisfactory result is only 15 per cent.; in capital necrosis without infraction, the percentage is about 70.

RESULTS

Roentgenographic Results

It is difficult to judge healing from a roentgenogram, and the surgeon has to be very critical to avoid erroneous conclusions that may have disastrous consequences. In order to designate the condition as unquestionable osseous healing, the entire fracture line should be crossed by trajectories from the neck into the head, without any zone of condensation.

TABLE XI

ESTIMATION OF FUNCTIONAL RESULTS IN RELATION TO HEALING AND NECROSIS OF THE HEAD

Group	No. of Patients	Healing		Necrosis of Head		Arthrosis		Necrosis of Head plus Infraction	
		(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)
I	50	50	100	0	0	3	6	0	0
II	41	40	97.6	17	41.5	21	51.2	6	14.6
III	51	36	70.6	37	72.5	39	76.5	30	58.8
IV	38	22	57.9	31	81.6	29	76.3	25	65.8

In Table IX is recorded the outcome of the roentgenographic re-examination of 180 patients. Healing was obtained in over 80 per cent., which may be considered a fairly good result. However, with increasing experience in the performance of these operations, more frequent postoperative control examinations, and more reoperations, it should be practicable to obtain a percentage of healing of nearly 100.

Functional Results

The functional results may be divided into four groups (Table X):

Group I. Ideal Results: The patient has no complaint, and the function of the hip is as good as before the accident.

Group II. Good Results: The patient has only slight inconvenience,—at the most, some "rheumatism" or rapidity of fatigue when a heavy weight is put on the hip. The walking capacity is about the same as prior to the accident. The physical examination may reveal a reduction in mobility of less than 10 degrees in each direction.

Group III. Fair Results: The patient complains of reduced mobility in the hip and a lowered working capacity. Pain is frequent; dressing is difficult. The physical examination shows some shortening and a considerable reduction in mobility. In some cases a moderate contracture may be ascertained.

Group IV. Poor Results: The walking capacity is greatly impaired or completely abolished. The patient's working capacity is approximately zero. Intense pain is present in the hip. The physical examination shows marked reduction in mobility, and at times pronounced contracture or even ankylosis.

Groups I and II correspond to what are designated in most other statistical studies as "good results".

One may wonder that the results are not better than as presented here. If the primary results had been estimated and recorded, no doubt they would have been far better, but it is the late clinical symptoms in cases with capital necrosis that put their stamp on the material. As previously mentioned, these late symptoms do not manifest themselves until about a year and a half after the accident.

In Group I (Table XI) all the fractures have healed and there is no capital necrosis, but three patients show roentgenographically a slight arthrosis that gives no symptoms. It is also evident that pseudarthrosis and capital necrosis with infraction and arthrosis are the cause of the poor functional results.

It would be interesting to compare the results of the Whitman treatment and osteosynthesis, but it is impracticable to obtain any reliable basis for such a comparison, because no fairly large study of Whitman-treated patients has been reported with a sufficiently long period of observation.

Furthermore, it must be emphasized that the material presented in this work comes from twelve different surgical departments and represents the first experiments with an operative method, which is well characterized by Mouchet in the following words: *En fait, il n'y a pas de procédé simple.*

POSTSCRIPT

The author has been able to present a group of patients treated according to the principles described herein. (Most of the patients were operated upon, and the after-treatment was given by the author.) This report covers all the patients who, during the period from 1941 to 1943, were given operative treatment for fracture of the neck of the femur in the Odense County Hospital,—a total of sixty-eight. Of this total, six died in the Hospital after the operation, and twelve died after discharge from the Hospital. The remaining fifty patients have all been re-examined clinically and roentgenographically after an observation period of at least three and one-half years, just as was done in the

TABLE XII

ROENTGENOGRAPHIC AND FUNCTIONAL RESULTS IN THE TWO GROUPS

Results	Old Material (180 Patients) (*No.*)	(*Per cent.*)	New Material (50 Patients) (*No.*)	(*Per cent.*)
Healing	148	82.2	47	94
Pseudarthrosis	32	17.8	3	6
Necrosis of the head	85	47.2	8	16
Ideal	50	27.7	39	78
Good	42	23.3	2	4
Fair	52	28.8	4	8
Bad	39	21.7	5	10

preceding study. Thus, the two groups of patients are similar and have been treated exactly alike, so that they are comparable in every respect.

The roentgenographic and functional results in the two groups are recorded in Table XII. After treatment of the patients according to the principles mentioned, the percentage of healing increased from 82 to 94, while the frequency of capital necrosis decreased from 47 per cent. to 16 per cent.,— that is, to one-third of the former frequency. This is reflected in the functional results, as in the second group 82 per cent. of the patients are found in the good class (Groups I and II) as contrasted with 50 per cent. of those in the previous study.

With our present knowledge concerning fracture of the neck of the femur and necrosis of the head, we may hardly expect to obtain better therapeutic results. Capital necrosis with subsequent arthrosis still threatens the late functional results in one of every six patients.

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THE USE OF THE TECHNIQUE OF PROGRESSIVE-RESISTANCE EXERCISE IN ADOLESCENCE *

BY J. ROSWELL GALLAGHER, M.D., ANDOVER, AND
THOMAS L. DELORME, M.D., BOSTON, MASSACHUSETTS

From the Department of Health, Phillips Academy, Andover, Massachusetts

In adolescence, such disorders as mechanical derangement of the knee joint, low-back strain, and insufficient development of the arms, shoulders, and chest frequently occur, and suggest the use of therapeutic exercise. Recently a technique has been reported [2,3,16] for the development of muscle power, which gives promise of being of considerable value. The basic principle of this technique, progressive-resistance exercise, is that muscle power is better developed by exercising a muscle a few times at its maximum capacity than by having the muscle repeat an exercise many times against less resistance. Special equipment and methods have been developed to permit the proper application of this principle [2,3].

The technique of progressive-resistance exercise has important implications beyond the strictly clinical field for those who deal with adolescents. It relates to that philosophy which in recent years has emphasized the abuse of rest [1,12,14] and the need for the development of fitness rather than the avoidance of strain and fatigue [6]; and takes issue with those physical educators who emphasize the social-psychological objectives of athletics and neglect the development of adequate muscle power and endurance [8]. It is obvious to most of us who deal with adolescents that strength needs to be developed as well as endurance, coordination, flexibility, and skill; and that, if injuries are to be avoided, some games [5] demand considerable strength about the joints. In addition, it is undoubtedly true that most activities will be performed more successfully and with less fatigue when greater strength and endurance are present; the individual will pay less physiologically, and therefore become less fatigued, when he is able to react well below his maximum limit.

This clinical report discusses the use of the technique of progressive-resistance exercise in the after-care of knee injuries and low-back strains and in the muscle development of the arms, shoulder girdle, and chest in adolescents. None of these will be discussed in detail here; it is the purpose of this report only to indicate the apparent usefulness of this technique in the care of these common conditions, and to suggest its value as an addition to other types of physical therapy.

KNEE INJURIES

The tendency of knee injuries to recur is well known, and the need for combating the atrophy and hypotonia of the extensor muscles of the thigh which accompany these injuries is all-important [13, 15]. Whether or not the ligaments are torn, whether the cartilage is damaged or removed, the most important part of the after-care of knee injuries is the development of strength in the quadriceps; frequently too much attention is paid to the lesion in the joint and too little to the subsequent development of power in the supporting muscles. Such exercises as quadriceps-setting, straight-leg raising, and walking are valuable in the early after-care of knee injuries and will gradually improve the power of the quadriceps; however, to prevent a recurrence of injury, it seems logical to us to strive for more than a return to former strength. Progressive-resistance exercises can restore the power lost, and can produce a much greater strength in the supporting muscles than they possessed prior to the initial injury. However, we do not feel that a knee joint

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which is free from fluid, has a normal range of motion, shows no atrophy of the thigh muscles, and can be vigorously extended against the examiner's resisting hand is necessarily ready for skiing, football, or other strenuous activities. These activities can, and do, put sudden and severe strain on the supporting muscles, far beyond the limits imposed at an examination. A knee joint is not ready for such stresses until it has extraordinary strength; absence of pathological signs is not enough.

Table I presents data concerning adolescents who were given progressive-resistance exercises for knee injuries. Twenty-five boys, ranging in age from thirteen to nineteen years, were treated. Two of them had previously had operations for the removal of a meniscus; one had considerable atrophy of the quadriceps following a dislocation of the patella; and the others had previously had tears of the collateral ligaments of varying severity. Careful clinical examinations were made and roentgenograms were taken before this type of physical therapy was begun. Those whose injury had been relatively recent were given a conventional course of heat and massage, patella-setting, and straight-leg-raising exercises before progressive-resistance exercises were started. In several cases, thigh-circumference measurements were made, and in every case quantitative estimates of the quadriceps strength were obtained by determining the maximum weight which the quadriceps had the power to raise to the horizontal (full extension).

At the first exercise period the maximum number of pounds which could be raised to the horizontal (Figs. 1-A and 1-B) was determined, as was also the maximum amount which could be extended by the patient when seated in the hip-knee extension exerciser (Figs. 2-A and 2-B). One is rarely able to obtain accurate maximum values at the first testing period. Much more valid data can be obtained at the beginning of the second week, and for that reason we have used data obtained at this second testing period as representing the patient's maximum power at the beginning of the therapeutic period. Each individual's prescription was determined on the basis of the maximum load he had the power to raise, or extend, ten times. If he was capable of raising no more than twenty pounds attached to the boot, he would be asked to raise ten pounds ten times, fifteen pounds ten times, and twenty pounds ten times on each day, four days a week. At the beginning of each subsequent week the patient's maximum power was again determined

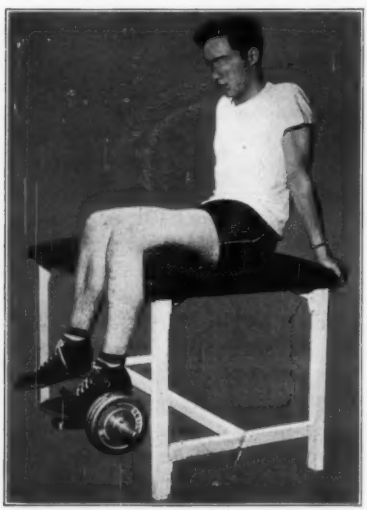

FIG. 1-A

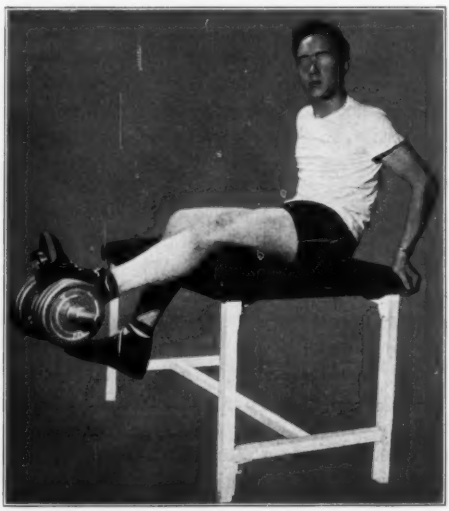

FIG. 1-B

Load-resisting knee-extension exercise.

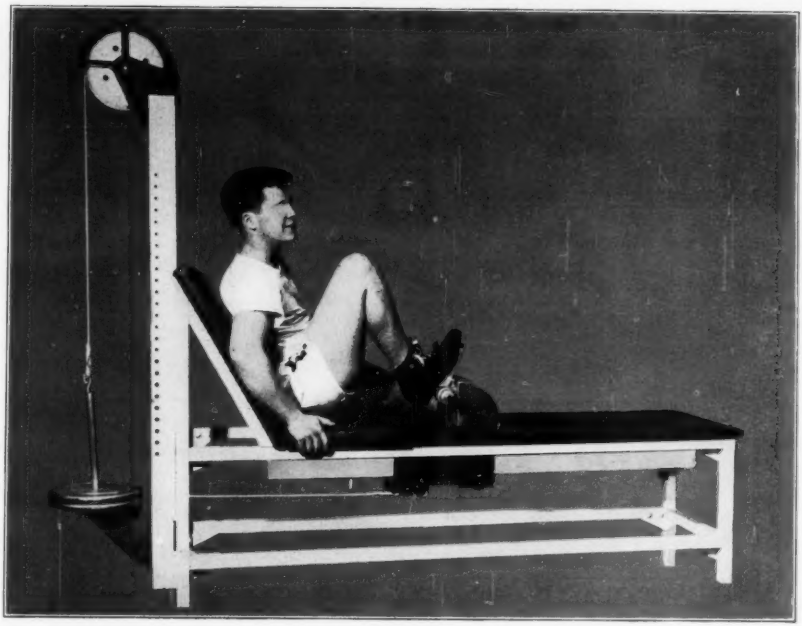

FIG. 2-A

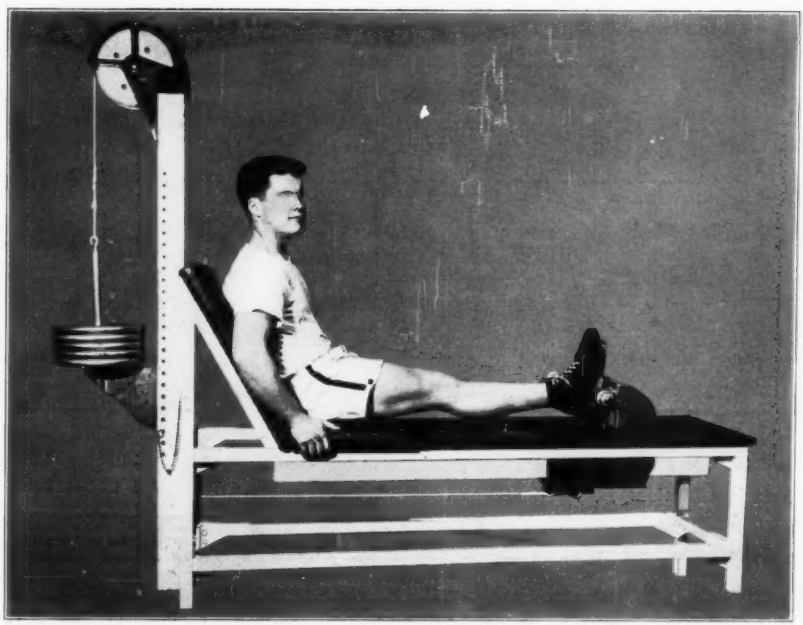

FIG. 2-B

Hip and knee flexion-extension exercise.

TABLE I

PROGRESSIVE-RESISTANCE LOW-REPETITION EXERCISE FOLLOWING KNEE INJURIES IN TWENTY-FIVE BOYS

Patient	Age	Height (*Inches*)	Weight (*Pounds*)	Diagnosis	Approximate Time from Injury to Start of Exercise Program	Maximum Power at Start of Second Week		Total No. of Exercise Periods	Maximum Power at Final Week		Interval between End of Treatment and Re-examination (*Months*)	Maximum Power at Re-examination	
						Hip-Knee Flexion-Extension (*Pounds*)	Knee Extension (*Pounds*)		Hip-Knee Flexion-Extension (*Pounds*)	Knee Extension (*Pounds*)		Hip-Knee Flexion-Extension (*Pounds*)	Knee Extension (*Pounds*)
H.A.	13	66	120	Collateral-ligament strain	2 years	50	27½	32	90	60	6	90	60
R.B.	16	72	155	Collateral-ligament strain	18 months	90	50	20	125	80	12	125	80
P.Br.	15	67	154	Collateral-ligament strain	4 weeks	65	40	40	130	80			
D.B.	16	66	109	Collateral-ligament strain	3 weeks	45	25	50	120	65	8	120	70
D.C.	17	72	177	Collateral-ligament strain and meniscus injury	6 weeks	70	50	20	110	65	2	110	80
S.C.	15	69	189	Collateral-ligament strain	2 weeks	110	50	24	130	80	9	125	85
I.C.	14	65	99	Collateral-ligament strain	6 weeks	30	12½	28	80	50	12	80	50
H.C.	15	69	149	Collateral-ligament strain	12 months	65	40	36	105	65	9	125	65
F.D.	16	69	155	Collateral-ligament strain	6 weeks	75	40	30	120	75	12	120	75
J.E.	19	69	152	Meniscectomy (postoperative)	4 months after operation	60	30	24	100	75	6	100	70

TABLE I (*Continued*)

P.E.	15	69	173	Collateral-ligament strain	6 months	—	45	36	—	90	9	—	95
J.F.	16	69	122	Collateral-ligament strain	18 months	60	30	24	105	70	5	110	75
K.G.	17	65	160	Collateral-ligament strain	3 weeks	70	22½	24	120	65			
A.G.	16	72	144	Collateral-ligament strain	1 year	35	5	40	90	70	9	100	70
R.H.	16	68	143	Collateral-ligament strain	6 months	85	35	18	125	70	10	125	70
H.J.	15	72	163	Collateral-ligament strain	1 month	80	60	34	110	75	6	125	65
K.L.	17	67	129	Collateral-ligament strain	4 years	65	30	20	100	70	5	100	80
J.O.	18	68	172	Collateral-ligament strain	4 weeks	90		28	120				
N.P.	17	70	180	Collateral-ligament strain	6 weeks	40	30	36	115	95			
T.R.	18	71	176	Collateral-ligament strain	4 weeks	80	35	28	120	65	10		70
K.S.	16	72	138	Dislocation of patella	8 weeks	40	25	44	105	65	4	105	60
G.K.	17	70	183	Collateral-ligament strain	6 months	75	30	24	110	65			
W.P.	17	70	169	Collateral-ligament strain	6 months	95	35	24	150	75			
L.S.	17	70	163	Collateral-ligament strain	8 months	60	20	24	110	55			
A W.	18	68	165	Meniscectomy (postoperative)	5 years after operation	85	45	20	130	85			

TABLE II

WEEKLY PRESCRIPTIONS IN CASE H.A.

Week	Pounds of Resistance in Load-Resisting Knee-Extension Exercise (10 Repetitions Each)			Pounds of Resistance in Hip and Knee Extension-Flexion Exercise (10 Repetitions Each)		
First	15	20	25	35	40	45
Second	22½	25	27½	40	45	50
Third	25	30	35	45	50	55
Fourth	30	35	40	55	60	65
Fifth	40	45	50	65	70	75
Sixth	45	50	55	70	75	80
Seventh	50	55	57½	75	80	85
Eighth	50	55	60	80	85	90

and his prescription was properly increased (Table II). The exercises were continued until the strength reached was greater than that of the contralateral limb, and beyond which we judged little progress could be made within a reasonable time.

It is clear from Table I that each of these boys became able to handle greatly increased amounts of weight within a relatively short period. In seventeen cases we have had an opportunity to determine whether the ability to handle this much weight would gradually be lost after the treatment stopped. The check-up intervals varied from two to twelve months. In no instance was there any indication that the gains made in the therapeutic-exercise period had been lost, although none of these boys had done any exercises of this nature during those intervals. Their retention of the gains made seems the more surprising because of the relatively high levels they had achieved.

Brief comments about a few of these cases may clarify the type of condition which is apparently benefited by this method, and illustrate a few points which have occurred to us in the course of this work.

H. A., aged thirteen, had injured his left knee in a fall from a horse, two years previous to our examination. He was in bed for six weeks and was told that he had injured his knee cartilage. He was not given any type of physical therapy or special exercise in the convalescent period. His knee continued to bother him "on and off, whenever I do much". He was a sturdy young boy, weighing 120 pounds, who wanted to play football. The examination of the knee was negative, and there was no evidence of quadriceps atrophy. He was told, however, that his muscle strength (he could raise twenty-five pounds on the boot and extend forty-five pounds on the hip-knee extension exerciser) was not good enough for the stress which football could offer; six-man football (a less hazardous game [8]) and an exercise program were suggested. After eight weeks of this exercise program he was raising sixty pounds and extending ninety pounds; during the next six months there were no symptoms referable to the knee, despite strenuous participation in athletics. A check, six months after he had discontinued therapeutic exercise, showed no loss in ability to extend these weights. The details of his weekly prescriptions (Table II) illustrate the "progressive" principle of this technique: Periodic increase in the maximum load is an essential part of this method.

I. C. badly twisted his right knee while skiing on February 23, 1947. He was admitted to the hospital where, on February 24, he was found to have considerable fluid in the knee joint, pain with all motions at the joint, and exquisite tenderness over the medial condyle. He had been treated with an ice pack initially, then with a tight compression bandage. After a few days of bed rest, the fluid disappeared. He was discharged from the hospital on March 3, without crutches, but with a supporting felt bandage. A period of quadriceps-setting and straight-leg-raising exercises followed. On April 5, 1947, a series of quadriceps measurements showed atrophy of the right quadriceps of from one-half to one inch at various points. Against a heavy spring scale he could extend his right leg against forty pounds, his left leg against sixty-five. In the hip-knee extension exerciser he extended twenty-five pounds with his right leg and thirty-five pounds with his left; he could raise only ten pounds on the boot with his right leg. After seven weeks of exercise he was able to raise forty-five pounds on the boot and to extend eighty pounds. Twelve months later he was still able to raise fifty pounds on the boot.

J. E. was operated upon in June 1947, and a ruptured medial meniscus was removed. He was given no postoperative exercise and was told "to be careful for a few months". He consulted us in October 1947. His knee seemed to be in fine condition and there was no atrophy of the thigh, but he could raise no more than fifteen pounds with his right leg (thirty-five with his left) and could extend only fifty pounds (eighty pounds with his left). This finding of strength differences when the loads are large, in the presence of an otherwise negative clinical examination, seems to us to be important. The joint motions are satisfactory, there is no fluid, the knee seems strong when the leg is raised against the examiner's hand, but there is relative weakness. After six weeks of treatment, J. E. was able to raise 75 pounds and to extend 100 pounds. Six months later he reported that he had had no trouble with his knee in the interval; a test showed that he had lost very little, if any, of his quadriceps power.

J. F. twisted his right knee while wrestling in June 1946; it did not seem to be a severe injury, and no treatment was given other than the application of an elastic bandage. In September 1946, the same knee "went out" at soccer, and he refrained from athletics for two weeks. In December he twisted his knee and fell in the shower bath. During the following spring and summer the knee bothered him, but he kept on trying various activities. In September 1947 his knee "went out" again at soccer and, completely discouraged, he decided to give up athletics. When seen by one of us on September 26, 1947, the knee seemed normal; there was no evidence of instability, no fluid, no crepitus or pain with motion, no atrophy of the thigh, and apparently good strength. The right leg, however, was able to lift only thirty pounds, while the left raised forty. After a seven-week program of progressive-resistance exercises, the right leg handled seventy pounds on the boot and increased its ability to extend from 55 to 105 pounds. During a test, five months later, he was still able to handle these amounts and had had no symptoms, despite an active athletic career during the winter and spring of 1948.

A. G. first had trouble with his left knee in October 1946; at that time there was evidently a considerable effusion in the joint and he was told that he had a "loose cartilage". A plaster cast was applied for three weeks; then diathermy treatments were given twice a week for six weeks, together with some quadriceps-setting exercises. In December 1946 he played basketball and injured his knee again; some fluid developed, but he tried skiing later that winter. He played baseball and tennis in the spring without difficulty. In September 1947 he slipped on a boat deck and wrenched his knee; fluid developed. When first examined by us (September 1947) there was a small amount of fluid in the left knee joint, but no tenderness to pressure or pain on motion; atrophy of the quadriceps was marked. The left leg could raise no more than five-eighths of a pound on the boot, and that was accompanied by apprehension and difficulty. A week later, when his confidence had been gained, he raised five pounds, which is undoubtedly a better measure of his initial strength. At the same time he lifted thirty pounds and extended sixty-five pounds without difficulty with his right leg, whereas he could extend no more than thirty-five pounds with his left. After ten weeks of exercise, he raised seventy pounds on the boot and extended ninety pounds with his left leg. A test nine months later showed no loss of power, and he had had no symptoms during these months.

K. S. dislocated his right knee (patella) while diving on July 25, 1947; a plaster cast was used until August 15. Fluid was present when the cast was removed, and diathermy and a whirlpool bath three times a week were ordered until September 12. When seen on September 15, he was still using crutches, and flexion and extension at the knee were considerably limited. There was no evidence of fluid, but there was marked atrophy of the right thigh,—from one-half to one and one-half inches in serial measurements. His right leg raised seventeen and one-half pounds on the boot, his left raised forty; the right extended thirty-five pounds, the left sixty-five. After nine weeks of progressive-resistance exercises he raised 65 pounds and extended 105 pounds with his right leg.

In these cases, not only has the atrophy or weakness of the thigh muscles been overcome, but the individual's ability to overcome weight resistance has been greatly increased over what we can presume was his ability prior to injury. This was accomplished with only a small expenditure of time; ten minutes a day is adequate. Patient cooperation is easy to obtain; these boys eagerly watched their charts and the gradual increase in power which they showed. The exercises, because they continually increase in difficulty, are challenging. They do not seem to be the same day after day, because the amount of weight is increasing and the numerical values act as an incentive and furnish the physician with an objective measure of progress.

The relatively rapid loss of cardiovascular-pulmonary endurance after cessation of a training program is well known [11]. The persistence of the weight-resisting ability is obviously much greater; there has been no significant loss in any of these cases. Exactly

what these exercises accomplish is not clear; the increase in weight which can be handled (in A.G. from five to seventy pounds and in J.F. from thirty to seventy pounds) cannot be thought of as representing a parallel increase in muscle mass or even in muscle strength. Learning factors at the cerebral level[10] undoubtedly play a part. Whatever the mechanism, atrophy has been overcome, and ability to raise or extend weight has been vastly increased. After the exercise program, each patient has felt much more confident of his knee's ability to withstand strain, and in none have any significant knee injuries developed subsequently. Obviously many more cases must be studied and a much longer period of observation must elapse before one can properly be optimistic. These preliminary observations, however, at least suggest the justification of further clinical tests of these methods.

LOW-BACK STRAINS

Symptoms of low-back strain are common in adolescence. During this period of rapid growth and strenuous, but poorly coordinated, exertion, there is frequently insufficient strength of the low-back muscles to prevent excessive strain being put on the lumbar and sacro-iliac ligaments. More uncommon disorders than postural or ligamentous strain, such as spondylolisthesis and epiphysitis, need to be kept in mind; and careful clinical and roentgenographic examinations of even the most transitory low-back symptoms are essential.

Experience to date indicates that progressive-resistance exercises in spondylolisthesis are tolerated well, often with relief of subjective symptoms. However, back symptoms may occasionally develop in patients with juvenile epiphysitis, probably due to excessive tension on the involved areas. Therefore, resistance exercises in these parts are advised with greater caution.

During the acute phase of low-back strain, bed rest, strapping, heat, and codeine and aspirin may be necessary. Later the patient should avoid lifting, a slumped position while sitting, and standing with the weight on one foot. Sleeping on a bed board, the daily performance of flexion and extension, and pelvis-tilting exercises are properly given. However, to prevent the recurrence of these symptoms, it would seem wise to attempt to increase the strength of the sacrospinalis[7]. This procedure may also be of value in the after-care of those who have previously had braces or casts applied. Data concerning nine

TABLE III

TRUNK-HYPEREXTENSION EXERCISE IN NINE BOYS

Patient	Age	Height (*Inches*)	Weight (*Pounds*)	Diagnosis	No. of Exercise Periods	Initial Maximum Power (*Pounds*)	Final Maximum Power (*Pounds*)	Maximum Power at Re-test (*Pounds*)
G.M.	17	74	181	Spondylolisthesis	10	10	25	
					20*	25*	70*	75 (6)**
J.B.	17	74	178	Low-back strain	18	45	65	75 (9)**
R.C.	16	70	150	Low-back strain	16	35	70	
N.K.	17	69	173	Low-back strain	24	20	80	
M.L.	16	69	138	Low-back strain	21	20	50	55 (12)**
R.S.	15	69	133	Low-back strain	36	20	65	75 (12)**
J.W.	18	69	155	Low-back strain	48	30	125	
H.M.	16	72	165	Epiphysitis, spine	24	20	50	
G.T.	18	69	128	Low-back strain	24	20	60	

* Second series, nine months later.

** Interval in months between exercise and re-test.

FIG. 3-A

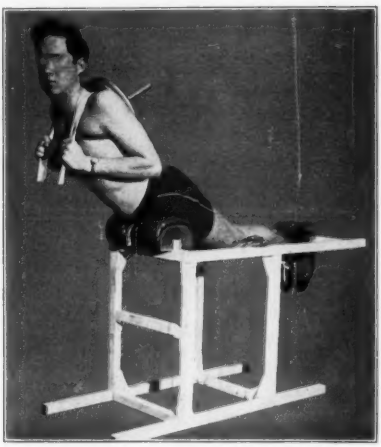

FIG. 3-B

Load-resisting exercise for hyperextension of trunk.

of these cases are given in Table III. The exercise method is illustrated in Figures 3-A and 3-B.

R. C. first hurt his back while pole-vaulting, in April 1947. In the early fall of that year his back was bothersome, and he decided to stop playing football. On October 9, 1947, roentgenograms were negative; there was slight limitation of forward bending, but no pain. Since there were no acute symptoms, progressive-resistance exercises were begun. The load-resisting trunk-hyperextension exercise (Figs. 3-A and 3-B), with weight placed between the shoulders just below the neck and with knees supported and feet firmly held, was done thirty times a day. During the first week twenty-five pounds was raised ten times, thirty pounds ten times, and thirty-five pounds ten times on each day. During the fourth week seventy pounds could be raised. No further symptoms developed, despite a resumption of pole-vaulting during the winter and spring. Five months later sixty pounds was raised without difficulty.

N. K., a sturdy and very athletic lad, first injured his back at football (tackling) in 1943; he was taped and was allowed to continue playing. In 1945 his back again bothered him. In the spring of 1947 he injured it at pole-vaulting and had to give up that sport. All through the football season of 1947 it bothered him, but he continued to play; it would feel tired and "sore" at night. At the start of early-season basketball, his back hurt whenever he jumped. At examination on November 13, 1947, when he finally reported his symptom to one of us (he had thought nothing could be done!), his roentgenograms were negative and so was his clinical examination, except for less flexibility in forward bending than one would expect in an athlete. Despite his excellent development and athletic skill, he could raise no more than twenty pounds when doing the back-extension exercise. During a three-month period of treatment (interrupted by the Christmas holidays) there were twenty-four exercise days; in this time he became able to raise eighty pounds. After the first week in January he had no further symptoms of back strain, and played basketball vigorously and without any discomfort.

R. S. first hurt his back in March 1947, while playing basketball out-of-doors; he was unable to sleep that night. Roentgenograms were taken, aspirin was ordered, and he was told to "take it easy". He recovered gradually and had no further trouble until spring, when he started to play lacrosse; his back was taped and he was told to rest for one month. At the end of May he played lacrosse again, but almost immediately his back started to hurt, so he stopped. In August, while swimming, it bothered and an osteopath made his bones "click". In the fall he tried football, but stated that his back hurt every day. Without much hope of obtaining relief, he consulted one of us on November 9, 1947. The roentgenograms were negative, and no abnormality was noted except discomfort during extreme forward bending. Progressive-resistance exercises, beginning with twenty pounds, were continued for two months (interrupted by the Christmas holidays). After thirty-six exercise periods, he could raise sixty-five pounds. At the end of four weeks (sixteen visits) he was able to hyperextend his trunk and fifty-five pounds, and later reported that during the Christmas holidays he shoveled heavy snow for three hours without discomfort. He wrestled during the winter and

played lacrosse during the spring without discomfort. Twelve months later he reported that he had had no symptoms of back strain since stopping his therapeutic exercise, and he was able to raise seventy-five pounds.

G. T., a physician's son, wrenched his back when he tripped going upstairs on February 27, 1947; it was very painful for him to straighten up, to walk, or to turn in bed. He was seen the next day; only slight forward bending was possible, and the lumbar muscles were in spasm. He was put to bed and given medication and heat. He gradually improved, so that one week later he could walk with comfort. Roentgenograms were negative. Because of the severity of that acute attack (there had been two similar attacks previously), progressive-resistance exercises were not started until April 7. At that time he was able to raise twenty pounds; six weeks later he was raising sixty pounds. Eighteen months later he reported that he had no further back pain.

H. M. had low-back discomfort in August 1945, and roentgenograms showed definite epiphysitis of the spine. A brace was worn until March 1947. With the consent of his specialist, progressive-resistance exercises were begun in April 1947; the back-extension exercise started with twenty pounds and increased to fifty pounds in six weeks. The patient subsequently engaged in a strenuous athletic program without difficulty.

J. W. fractured his coccyx in 1943. In December 1947, he returned to his physician for an annual checkup. He was told that he probably would have trouble with his back at the age of forty; and was urged, as he had been during the previous four years, to continue to take it easy at athletics. After his return to school he came in requesting a bed board, because his back ached sometimes. Roentgenograms and clinical examination of his back were negative; his abdomen was prominent, and the muscles in general were rather flabby. Despite his lack of interest in exercise and athletics, he said he wanted to get rid of his prominent abdomen and wouldn't mind seeing if he could prevent his backache and avoid the trouble promised for the age of forty. With some skepticism and a little indifference, he began back-extension exercises on January 26 with twenty-two and one-half pounds, and continued until May 14, when he was able to raise 125 pounds. Concurrently he did "sit-ups", first against only his own weight, and finally doing thirty a day with twenty pounds held by his hands behind his neck. He had no symptoms of back strain after March 1 and slept without any discomfort. In May his muscles were firm, his attitude and spirits had improved, and his abdomen was no longer prominent.

There has been an opportunity to test four of the nine boys at intervals of from six to twelve months after the special exercise had been discontinued. In no case was there a loss in ability to raise the amount of weight which had been their previous maximum (Table III).

CHEST AND ARM DEVELOPMENT

Examinations of adolescents which seek ways to improve health and fitness, as well as to uncover abnormalities[4], will frequently reveal youths whose arms are extremely thin, whose chests are flat, and whose shoulder girdles are poorly developed. It would

TABLE IV

EXERCISES FOR THE DEVELOPMENT OF ARMS, CHEST, AND SHOULDER GIRDLE IN EIGHT BOYS.

Patient	Age	Height (*Inches*)	Weight (*Pounds*)	No. of Exercise Periods	Curl *	Alternate Press *	Side Arm-Raising *	Side Arm-Raising (Lying) *
I.C.	14	65	99	40	15–25	10–15	5–8¼	5–8½
C.C.	15	71	126	36	30–50	12½–20	5–11¼	7½–13¾
J.G.	14	64	110	60	20–32½	7½–11¼	2½–6¼	2½–8¾
L.K.	14	62	91	32	20–30	7½–15	2½–6¼	2½–7½
C.P.	17	69	132	46	35–60	12½–30	5–10	7½–17½
A.P.	15	71	172	24	20–50	10–25	2½–8¼	5–10
H.S.	16	68	127	36	25–45	10–20	6¼–10	7½–11¼
J.S.	15	69	133	36	30–45	10–20	5–8¼	5–12

* The first number represents the initial maximum power, the second number the final maximum power.

seem reasonable to believe that improvement in these conditions would be beneficial. The youth who does not wish to be bigger and stronger is rare; and, if for no other reason than to satisfy these wishes, it is proper to try to help him. To take the position that brains are all-important and to deny the part that brawn plays in an adolescent's mental health and adjustment is unfortunate. These exercises may be considered more properly a part of a physical-education program than the concern of the physician, pediatrician, orthopaedic specialist, or physical therapist, but often they can be combined with exercises for the back, knees, or some other region which brings the patient in for treatment. Too few physical educators or athletic coaches spend much effort in the improvement of strength of the less able athletes; many of them are interested chiefly in the development of skill and in the psychological values of games. An indication of the sort of gains which can be made is given by the data in Table IV.

I. C. came in for quadriceps exercises, but wished also to build up his chest, arms, and shoulders. Over a period of ten weeks he made considerable gains in ability to handle increasing amounts of weight in doing each of four exercises.

J. G. is of interest because his exercise period was interrupted and because he was again tested after a nine-month interval without similar exercise. In this nine-month interval he had taken part in a regular school program of soccer, basketball, and lacrosse; and yet, although there was no loss in ability to handle as much weight as he had done nine months previously, it was difficult for him to do so and there certainly had been no gains in strength. In sixty exercise periods (Table IV) his ability to handle weight increased from 50 to 250 per cent. for the various exercises.

CONCLUSIONS

On the basis of this preliminary experience with progressive-resistance exercises in these conditions of adolescence, it seems obvious that the method is a valuable adjunct to other physical-therapy procedures. The objective nature of the exercises, the fact that numerical values can be assigned and progress charts kept, and the fact that new and strange equipment is used all contribute to the patients' interest and cooperation. It would appear that the benefits of these procedures persist over a considerable length of time; further study of this point is obviously necessary. More investigation of the nature of the improvement in ability to handle weight is also needed. Other factors than muscle hypertrophy must exist to explain the changes noted. The concomitant improvement in the contralateral limb has not been discussed, but in each of these cases it has been noted; and it has been described by Hellebrandt, Parrish, and Houtz.

SUMMARY

1. This preliminary report suggests the effectiveness of the technique of progressive-resistance exercise in the after-care of knee injuries and low-back strains and in the development of the muscles of the upper trunk and arms of adolescents.

2. The desirability of utilizing a therapeutic-exercise method which will not only restore muscle power, but which will also produce a considerable increase over the strength existing prior to injury, is urged.

3. Further clinical trial of progressive-resistance exercise is suggested in conditions which require that muscle power be increased.

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AN UNUSUAL FORM OF DE QUERVAIN'S SYNDROME

REPORT OF TWO CASES*

BY IAN D. MURPHY, M.D., VAN NUYS, CALIFORNIA

From the Orthopaedic Section, Birmingham Veterans Administration Hospital, Van Nuys

In most cases of de Quervain's syndrome, the tendons of the abductor pollicis longus and the extensor pollicis brevis are involved, as they pass diagonally downward in a common compartment over the styloid process of the radius [2]. Occasionally the tendons lie in separate compartments, and the pathological process may involve either or both [3] (Fig. 1). In the cases reported here, the constriction was limited to the tendon and separate sheath of the extensor pollicis brevis.

CASE 1. A negro dishwasher, forty-seven years old, complained that pain in the left wrist had persisted for five weeks. The pain was especially severe on adduction and passive ulnar deviation of the thumb. Localized swelling, heat, and tenderness were present just above the radial styloid process.

At operation, under the ischaemia produced by a pneumatic tourniquet, the superficial branches of the radial nerve were identified and retracted. A transverse incision was used to avoid the ugly keloid frequently seen after longitudinal incisions. The tendons of the abductor pollicis longus and extensor pollicis brevis lay

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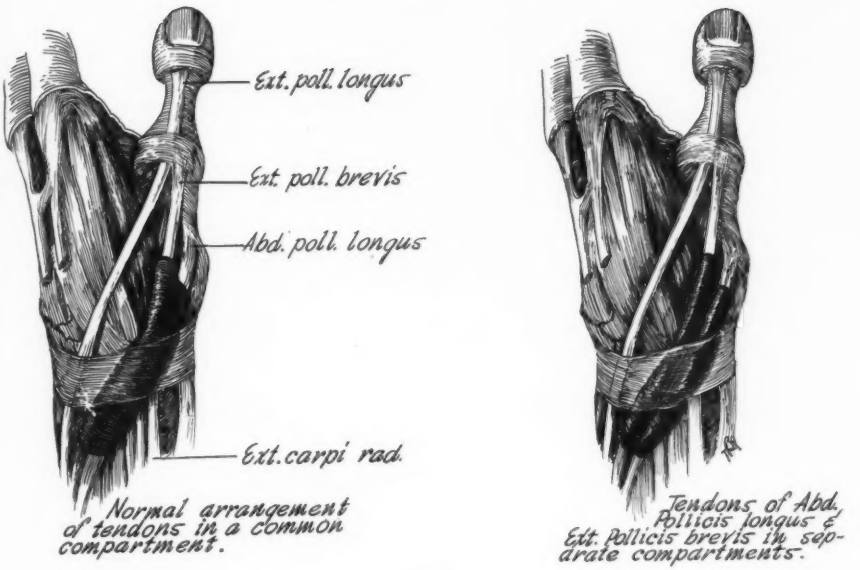
Ext. poll. longus
Ext. poll. brevis
Abd. poll. longus
Ext. carpi rad.
Normal arrangement of tendons in a common compartment.
Tendons of Abd. Pollicis longus & Ext. Pollicis brevis in separate compartments.

FIG. 1

in separate compartments (Fig. 1). The sheath over the abductor tendon was opened and was found to be of normal appearance. A probe was easily slipped up and down the sheath beneath the dorsal carpal ligament, and no aberrant tendon was encountered, as is frequently reported [1]. The sheath of the extensor pollicis brevis was next incised; it was thickened, discolored a reddish-brown, and contained yellowish fluid. Probing revealed the constriction to be one inch above the radial styloid process. A section of the dorsal carpal ligament and the sheath was excised longitudinally to a point well above the constriction, and the tendon then moved freely in its compartment with abduction of the thumb. Only the subcutaneous tissues and skin were closed.

Microscopic section revealed synovial tissue of tendon-sheath origin, lined by proliferated and hypertrophied mesothelial cells, the stroma of which presented moderate fibrosis. Recovery was uneventful; six weeks later the patient was working and had no symptoms.

CASE 2. Symptoms identical with those of Case 1 had been present for two months in a seventy-year-old white retired textile manufacturer, whose most strenuous activity for the past five years had been golf. The pathological findings were also the same, being confined to the tendon of the extensor pollicis brevis, which was in a separate compartment. As in the first case, the treatment consisted in removing a section of the dorsal carpal ligament and sheath at the point of constriction. Immediately afterward, the patient could fully abduct and extend the thumb.

In these two cases with symptoms of de Quervain's syndrome, the constriction involved only the extensor pollicis brevis, which was in a separate compartment. When this less usual arrangement of the tendons occurs, exploration of both compartments is advised.

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A METHOD OF PROCURING ILIAC BONE BY TREPHINE CURETTAGE

BY WALTER SCOTT, M.D., HOLLYWOOD, RALPH C. PETERSEN, M.D., GLENDALE, AND SIDNEY GRANT, M.D., LOS ANGELES, CALIFORNIA

An easy method of procuring cancellous bone from either the anterior or the posterior portion of the iliac wing is presented. Essentially, it requires a one-inch incision, stripping of a small portion of the crest, and the excision of a piece of cortex sufficient to admit a medium-sized curette. This is followed by complete curettement, bone being taken from a 45-degree arc in each direction (Fig. 1). The use of a suction apparatus facilitates the procedure considerably. Before closure of the incision, it is advisable to pack the cavity with a hemostatic substance, such as gelfoam, to prevent the formation of hematoma.

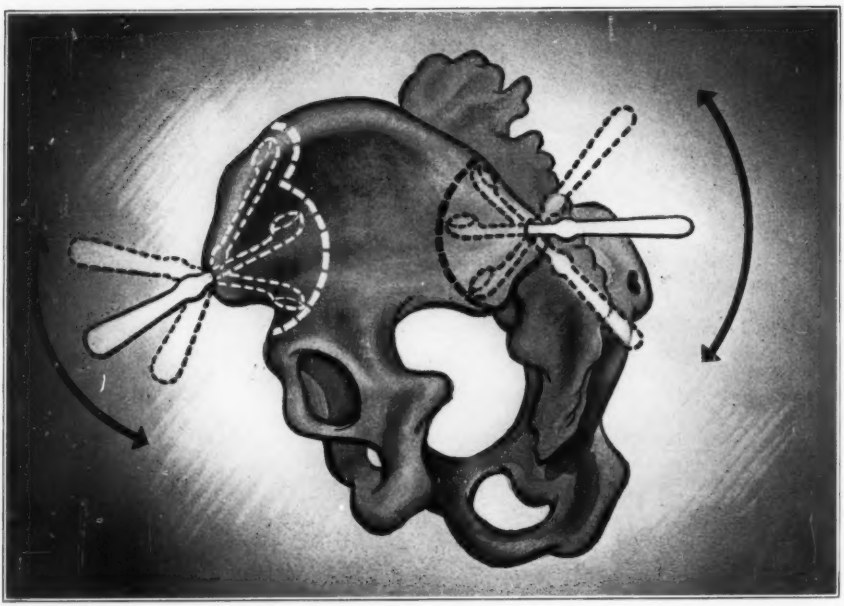

FIG. 1

This procedure has been used by the authors in approximately 150 cases. There have been no complications, and, as there is practically no shock, the method can be used in the aged patient or in the acutely injured, where the conventional and more extensive iliac operations are precluded.

In our experience, curettings are superior to cancellous chips, cubes, or slivers, principally because the material can be better molded and packed into the bone cavities at the recipient site. Muscle stripping is entirely eliminated, making early ambulation possible.

VITALLIUM-CUP ARTHROPLASTY OF THE HIP JOINT

Review of Approximately One Hundred Cases *

BY ALEXANDER GIBSON, F.R.C.S. (ENG.), WINNIPEG, MANITOBA, CANADA

There are two qualities that every joint should possess,—stability and mobility. In the upper limb, mobility is the keynote; in the lower limb, stability is more important. In the hip joint, stability is largely assured by the massive construction and comparative fixity of the pelvic girdle, while mobility is provided for by the presence of a ball-and-socket joint, permitting movement in all directions.

In order that this enarthrodial joint may function at its best, the position of the fulcrum must be at an exact distance from the line of the center of gravity. If fulcrum and line of gravity are approximated, stability may be increased, but there is a loss of mobility; if they are distracted beyond the normal, there is a loss of both stability and mobility. If the "machining" of the joint components be defective or the lubricating mechanism imperfect, there is a loss of efficiency; and, if the muscle control is deficient, the same result accrues. Of all the factors necessary to the smooth working of a hip joint, probably failure of muscle control is the earliest to make itself manifest. The work of Inman has demonstrated beautifully the muscular mechanics of the hip joint in regard to the movement of abduction. The factor of distraction of the head of the femur was dealt with by Gilmour under the caption, "Increased Acetabular Depth". Wiberg has emphasized this and has suggested a method of measurement.

It seems a natural inference that this outward passage of the head is due to inadequacy of the muscles which serve to hold it in the acetabulum. These are muscles of which we hear comparatively little; they are of considerable mass and they run for the most part

TABLE I

Measures for the Relief of Pain

Manipulation	Drilling of the head of the femur
Osteotomy	Division of the obturator nerve
Cheilotomy	Division of the fourth lumbar root
Joint débridement	Acetabuloplasty
Reconstruction (Whitman or Colonna)	Capsulectomy
Bone block	Chordotomy
Muscle-flap transplant	Arthroplasty (either without any barrier, with fascia, or with some form of mold)

transversely from the pelvis to the upper end of the shaft of the femur. These muscles are the pectineus, quadratus femoris, adductor magnus (uppermost portion known as adductor minimus), piriformis, obturator externus, and obturator internus with the two gemelli. This reasoning suggests that muscular insufficiency is an important factor in the development of osteo-arthritis of the hip joint; and that the deformities of the head of the femur and of the acetabulum are not merely phenomena of degeneration, but are partly physiological bone reactions to misdirected physical strains. This would align the condition with what is seen so frequently in the lumbar spine, and would suggest the value of muscular exercise, preferably without weight-bearing, as a prophylactic measure.

The osteo-arthritic hip has one outstanding symptom, pain, and one outstanding sign, limitation of movement. Of the two, pain is the more insistent problem. For its alleviation, many measures have been adopted (Table I).

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 4, 1948.

TABLE II

Disability	Number of Cases
Osteo-arthritis	89
Atrophic arthritis	9
Marie-Strümpell disease	3
Ununited fracture	3
Tuberculosis	2
Slipped epiphysis (old)	2
Septic arthritis	2
Fracture-dislocation	1
Total	111

The present paper deals with about one hundred cases in which a Vitallium cup was employed, following the method of Smith-Petersen. It is in no sense a scientific memorandum. The patients came mainly from long distances; their stay in the hospital was for the most part limited by financial and other considerations. In the majority of cases there was only perfunctory after-care, and many of the patients have not been heard from directly since they left the hospital. Indirect reports have been numerous, but in most instances it has not been possible to check progress. Thus it is a series of impressions rather than a statistical survey that is presented.

Age of the Patient

The average age was 52.6 years; the oldest patient was seventy-six, the youngest, sixteen. While there has been some improvement in the older patients, notably in regard to pain, the results have been rather disappointing. In older people there is not the capacity for exercise and the will to improve that are seen in younger individuals. We have tended to set the age of sixty-five as an arbitrary upper limit for this procedure. On the other hand, the two youngest patients, aged twenty-three and sixteen, gave poor results. The most encouraging progress was made by patients in the fifth decade.

Stage of the Disability

Most of the patients treated surgically were in a fairly advanced condition with much osteophytic outgrowth, loss of articular cartilage, and limitation of movement. The author has moved toward the position that an earlier attack on the problem, before these changes had become so marked, would have given better results. In a community where most of the population live by physical labor on the farm or on the railroad, medical aid is not sought until the malady has become disabling or the pain intolerable.

Cause of the Disability

The causes of disability are indicated in Table II. The cases of osteo-arthritis were, on the whole, suitable for this form of treatment. Atrophic arthritis proved less satisfactory, and the cases of Marie-Strümpell disease were wholly disappointing. Of the two cases of tuberculosis, in one the procedure was undertaken deliberately and in the other the infection was a belated discovery. In both the treatment failed; both patients had arthrodesis later with satisfactory outcome. Of the three cases of ununited fracture of the neck of the femur, one had a satisfactory result and the other two did not. Of the two cases of slipped epiphysis, one patient, aged thirty-three, is at latest report free from pain, but is still using a crutch. The other, aged sixty-one, suffered dislocation of the cup from the acetabulum, the roof being very sloping. Fusion of the joint was performed later. Of the two cases of septic arthritis, gradual stiffening occurred in one; at a later date

TABLE III

Result	Number of Cases
Good	65
Satisfactory	16
Bad	19
Unclassified	11
Total	111

the head of the femur was excised. The other was the result of a severe war injury. The result, while not spectacular, is regarded as a success, inasmuch as the patient is now able to drive a car and manages a small business of his own. A good result was obtained in the case of fracture-dislocation.

THE SURGICAL APPROACH

In every case, the hip joint was exposed by the "posterior" approach, based upon that described by Kocher. It has proved to be very simple, thorough, extensible to any degree, and almost bloodless; it is unaccompanied by shock. It is rarely necessary to tie a blood vessel; no patient has ever required or had a blood transfusion; and there has never been a hematoma in the wound. There is no extensive detachment of muscle fibers from bone; the glutaeus medius and glutaeus minimus run no risk of shortening. Replacement after reflection is easy and accurate. There is no interference with the function of the iliotibial tract. After recovery, the Trendelenburg sign is usually negative. The description of this approach sounds complicated; in practice it is exceedingly simple. As many surgeons seem to be unfamiliar with the method, a brief description is given herewith.

The So-Called "Posterior" Approach *

1. The skin incision is made from a point about two inches (five centimeters) in front of the posterior superior spine of the ilium, in a straight line or a slightly forward curve, downward to the upper anterior angle of the greater trochanter; from this point it passes vertically downward along the lateral aspect of the thigh for six or seven inches. When the skin and fat have been reflected, the anterior border of the glutaeus maximus will be revealed.

2. The fascia lata should be incised in the line of the femur. This incision is followed upward along the anterior border of the glutaeus maximus, and the muscle is reflected backward. This avoids bleeding from the muscle.

3. The posterior border of the glutaeus medius is then evident, and is separated from the adjacent piriformis tendon. The border is followed down to the insertion on the lateral aspect of the greater trochanter, and this insertion is detached with a flake of bone if necessary. The operator should then proceed around to the anterior surface of the greater trochanter, and detach similarly the glutaeus minimus at its insertion. Both of these muscles are reflected forward.

4. The insertion of the piriformis is detached from the highest point on the greater trochanter, and the muscle is reflected backward. The upper aspect of the capsule is then laid bare.

5. The joint capsule is incised from the rim of the acetabulum to the upper aspect of the neck of the femur, thus opening the joint cavity.

6. The femoral attachment of the capsule is detached from the anterior intertro-

* A more detailed description of this procedure will be included in an early issue of the British Volume of *The Journal.*

chanteric line, as far as is necessary to provide easy egress for the head of the femur. It is never necessary to touch the iliopsoas.

7. The head of the femur is then dislocated through the opening in the upper anterior portion of the capsule. The knee is flexed; the thigh is rotated strongly outward and is adducted. When this has been done, the field of operation is completely in view.

8. The periphery of the acetabulum is freed from excessive bone growth. The floor of the acetabulum is inspected, and any loose pieces of bone or redundant synovial membrane are removed. The bony floor is usually smooth and is not weakened by burring out compact bone.

9. The head is remodeled roughly with an osteotome, then with a short wood rasp which is controlled with the finger tip, and finally with a reamer.

10. The cup is fitted so that it moves easily and smoothly, but does not "rattle". The neck is freed from projecting spurs of bone.

11. The cupped head is reinserted into the acetabulum by reversing the extrusion manoeuvre. The flap of capsule is stitched back into position.

12. The glutaeus medius and glutaeus minimus fold back into position and are stitched with catgut; the glutaeus maximus and fascia lata are similarly disposed of; the skin is closed with a continuous suture. Although the wound is fourteen or fifteen inches long, it heals readily.

Postoperative Treatment

The period spent in bed is usually four weeks, during which exercises are carried out. Three principles are observed in regard to exercises.

First, they are graded, as follows:

1. Assisted: The strain is eased by the use of pulleys and counter suspension.
2. "Scratch": The limb is actively moved without assistance.
3. Handicapped: Resistance is added in the form of a weight which is systematically increased. If weight is added too rapidly, progress is retarded.

Second, the exercises are carried out in all directions. In the case of a disabled knee joint, we are constantly adjured to institute "quadriceps" exercises. Experience has shown that "hamstring" exercises are at least as important, and so, in the case of the hip joint, exercises must include flexion, extension, abduction, adduction, external rotation, and internal rotation. Special attention is paid to abduction.

Third, it is recognized that the movements of the hip joint and those of the lumbar spine are complementary; hence exercises for the back are carried out as faithfully as those for the hip itself.

COMPLICATIONS

Breaking of the Cup: In no case has this occurred.

Infection: In one case infection flared up suddenly during the third postoperative week. As it did not respond to conservative measures, the cup was removed.

Dislocation: Dislocation occurred in three cases. One of these was an ununited fracture of the neck of the femur in a woman weighing about 250 pounds. The stump of the neck was too short. A second occurred in a patient who had an attack of pneumonia shortly after returning home. He lay constantly on the sound side, and the upper end of the femur was displaced from the cup. It was replaced by manipulation nearly three years ago, and there has been no trouble since. In the third case, the cup was displaced from the acetabulum. It was an error of judgment to have placed a cup in a socket with an inadequate roof. The error was corrected by subsequent arthrodesis.

Bone Absorption: A fairly constant finding was that the cup sinks into the depth of the acetabulum, and that the stump of the neck seems to shorten as if it also underwent absorption. In some instances a layer of sclerosed bone seems to be laid down to oppose

FIG. 1-B

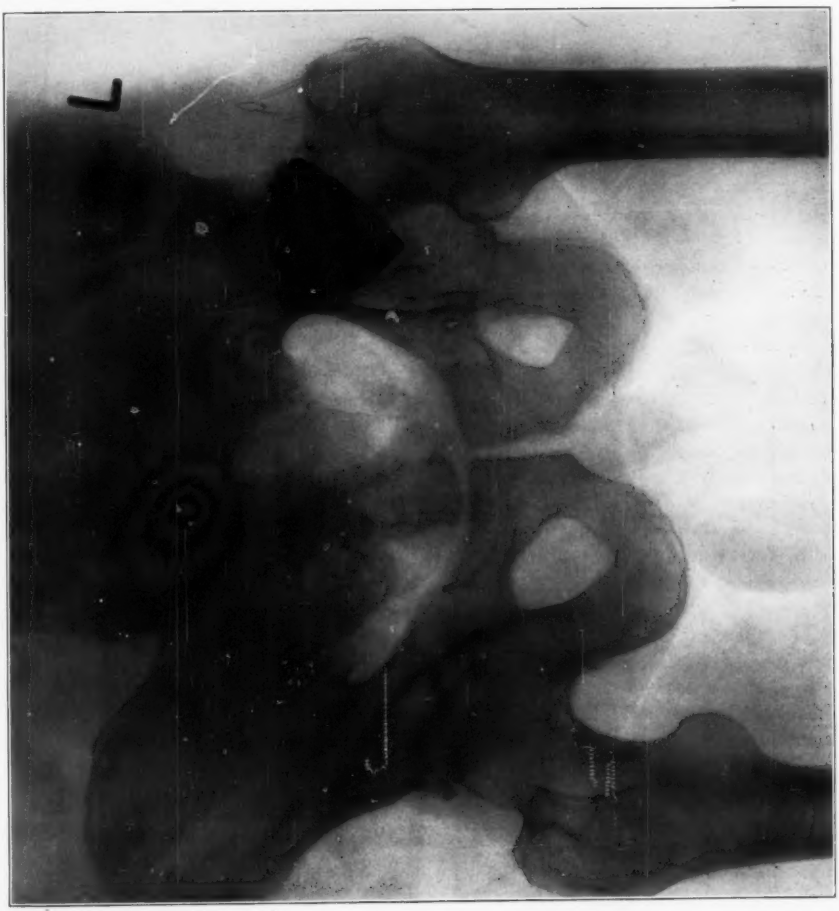

FIG. 1-A

Fig. 1-A: Case 1. September 8, 1949, ten years after operation. Shows absorption of the neck and sinking of the cup into the acetabulum.

Fig. 1-B: September 8, 1949. Lateral view of hip.

FIG. 2-A
Case 74. May 17, 1939, before operation.

FIG. 2-B
June 11, 1949, eight and one-half years after operation.

this migration. No pain accompanies this gradual displacement, although movement becomes less free. The picture suggests that, at least in old cases, the main part of the movement in the reconstituted joint takes place between the upper end of the femur and the cup, rather than between the cup and the acetabulum. A corollary to this observation would seem to be that it is inadvisable to burr out the cavity of the acetabulum, as this procedure must expose softer bone to the pressure of the metal.

Transient Drop-Foot: This was noted in one case, and was attributed to stretching of the sciatic nerve in the process of extrusion of the head from the acetabulum. In the customary exposure, the sciatic nerve is never seen.

Spur Formation: In one case, complaint of pain led to re-exposure of the hip. A ridge of bone was present on the under side of the neck. Removal of this spur (in 1941) gave complete and permanent relief.

Suture Material: In a few cases, stout silk was used to ensure firm closure of the capsule. In two instances, these silk sutures worked out at a later date. Apart from a chronic discharge, there was no inconvenience.

BILATERAL CASES

There were five bilateral cases, with one death; this occurred six months after the second operation, as a result of arteriosclerosis with gangrene of the foot. The results in the other four cases were satisfactory. One patient has been operating a taxi since 1942; another, aged seventy-six, is still able to get about with canes; another is working on his farm. A fifth patient, whose result had first been classified as "bad", came back to have the other hip made equally free from pain.

MORBIDITY

There were no operative deaths. Five patients have died since the operation, one, referred to in the preceding paragraph, at the age of sixty-eight. Another, aged seventy-six, died a month after operation from cerebral arteriosclerosis. A third died from the same cause at the age of seventy-six; a fourth died five years after operation at the age of sixty-

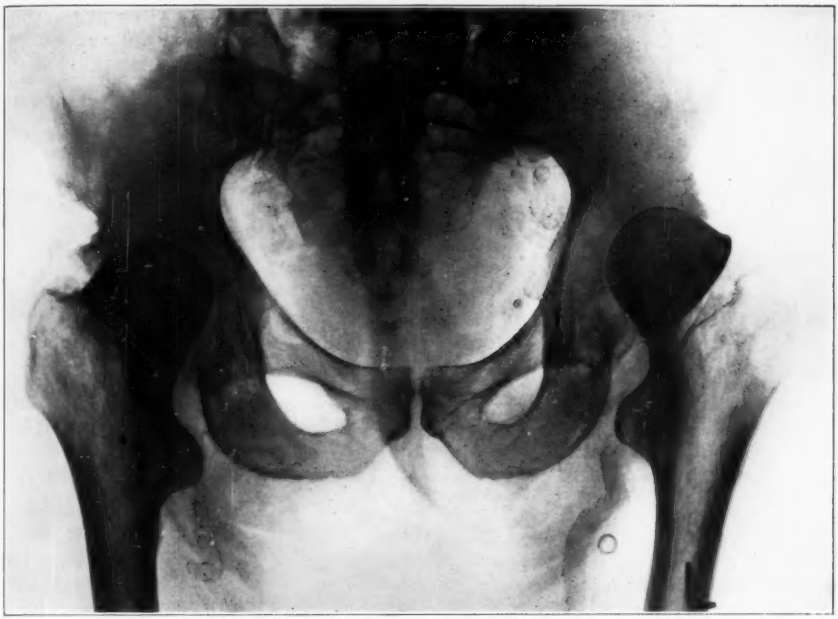

FIG. 3

Case 43. Appearance of hips on May 14, 1946, sixteen months after second operation.

nine, likewise from arteriosclerosis. The fifth patient died one year after operation from secondary carcinomatous growths in the pleura and spine. As far as is known, there have been no deaths among patients operated upon since 1942.

RESULTS

It is impossible to present an accurate picture. All cases should theoretically be considered under three categories,—anatomical, functional, and economic. In considering movement alone, a three-dimensional joint demands three-dimensional coordinates which have to be correlated. This would entail the use of an index of mobility, active and passive, checked at intervals,—a measure adopted in only a few cases of the present series. The sole criterion used has been functional efficiency. When the outstanding indication for operation is the relief of pain, it should be obvious that the patient must have a voice in estimating the result. The result is considered "good" when the patient can earn his own living and indulge in a moderate amount of physical recreation, such as curling or golf. He should also be able to put on his own socks and shoes, and should be able to stand firmly on the foot of the affected side. Many have attained such results (Table III). A "satisfactory" result is one in which the patient is completely relieved of pain during his ordinary activities. This has been attained in the great majority of cases. A "bad" result is one in which the surgeon or patient, or both, are disappointed. Of these, there are nineteen in this series. They include the cases of tuberculosis, of Marie-Strümpell disease, and others which better selective judgment or better operative technique would have excluded.

ARTHROPLASTY OR ARTHRODESIS?

Inevitably one ponders the question of arthroplasty or arthrodesis. In some cases, such as tuberculosis, there is no choice; arthrodesis is imperative. In other cases, where,

for example, there is bilateral ankylosis, an attempt to secure movement on at least one side is equally imperative. Both measures, if successful, give promise of relief from pain. If a reasonable degree of stability can be secured with, at the same time, a reasonable degree of mobility, then arthroplasty is the first choice. If only in a hip joint, a certain measure of freedom is surely worth the sacrifice of a modicum of security.

ILLUSTRATIVE CASE HISTORIES

CASE 1. A. le M., aged fifty-eight, a market-gardener, was completely disabled on account of osteo-arthritis of the hip. The operation was performed on July 3, 1939. He left the hospital in two weeks, had no postoperative treatment, and has been free from pain since. He regained good movement of the joint, was able to cross one leg over the other, and to sit in comfort through an entertainment. The patient was last seen on September 8, 1949 (Figs. 1-A and 1-B). There is still practically no pain, but the movement is less. He works from dawn to sunset, drives a car, and is satisfied. Functionally and economically, the result is good.

CASE 74. B. H., a stenographer, was operated upon at the age of thirty-eight. She had suffered from atrophic arthritis since the age of nineteen. Her left hip joint had been affected since 1938. The right knee was stiff (fibrous ankylosis) (Fig. 2-A). The operation was performed on January 5, 1941. The patient was in the hospital for four and one-half weeks, and did not use crutches after that time. She returned to work in from seven to eight weeks. This woman has had no pain since her operation, and has lost no time from work. Roentgenograms show considerable sinking of the cup into the acetabulum, and absorption of the neck of the femur. The patient was last seen on June 12, 1949 (Fig. 2-B).

CASE 43. J. P. had been a groom and a coachman; when seen, he was on old-age pension. He had marked osteo-arthritis of both hips with disabling pain. He was seventy-one at the time of his first operation, on June 16, 1943. He obtained relief from pain, and asked for an operation on the second hip. This was done on January 5, 1945 (Fig. 3). When last seen, on June 15, 1949, the patient walked with two canes, but stated that he was relatively free from pain unless he did too much. This case is classed as satisfactory, although the patient himself thinks the result is good.

CONCLUSIONS

1. Vitallium-cup arthroplasty offers good prospects of relief from pain and increased movement in cases of osteo-arthritis of the hip joint.
2. The "posterior" approach affords excellent exposure with little trauma.
3. Graded exercises in all directions are valuable for rehabilitation.
4. The procedure has not been found suitable in cases of tuberculosis, Marie-Strümpell disease, or sloping of the acetabular roof.

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DISCUSSION

DR. M. N. SMITH-PETERSEN, BOSTON, MASSACHUSETTS: I think Dr. Gibson has proved that, if we can do a thing well in our own way, we may occasionally succeed. He has demonstrated a different method of arthroplasty than the one we advocate. There are several points upon which we disagree.

I have always felt that, if we are to create a joint, we must create a joint that will be mechanically

(*Continued on page 872*)

POSTERIOR DISLOCATION OF THE HIP WITH FRACTURE OF THE HEAD OF THE FEMUR

BY EVERETT J. GORDON, M.D., AND JOSEPH A. FREIBERG, M.D., CINCINNATI, OHIO

From the Department of Orthopaedic Surgery, College of Medicine, University of Cincinnati

Traumatic dislocation of the hip comprises from 2 to 5 per cent. of all traumatic dislocations. As the precipitating injury is always one of great violence, a complicating fracture is not uncommon; this usually involves the posterior rim of the acetabulum. A fracture of the head of the femur accompanying posterior dislocation of the hip is rare; it has been reported infrequently in the literature. Such a case is described here.

It is generally agreed that the cause of fracture of the head of the femur, in conjunction with posterior dislocation of the hip, is either direct trauma to the greater trochanter, or, more frequently, a powerful upward force exerted against the anterior aspect of a knee held in 90 degrees of flexion.

The fracture of the head of the femur appears to occur in its inferior or antero-inferior third; the fragment may be attached to the ligamentum teres and may or may not remain within the acetabulum, thus affecting the choice of procedure for reduction.

CASE REPORT

J. C. (Hospital No. 213614), a white male, thirty-two years old, was admitted to Cincinnati General Hospital on May 7, 1946, after the automobile which he had been driving had crashed into a tree. On initial

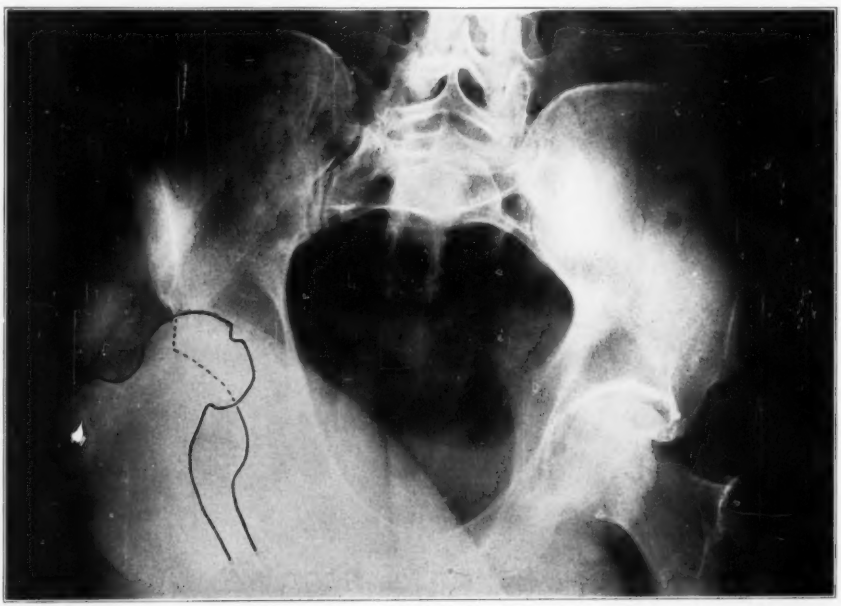

FIG. 1

Complete posterior luxation of femoral head. (Detached fragment from head is not demonstrable in this film.)

FIG. 2

Femoral head has been completely reduced into the acetabulum.

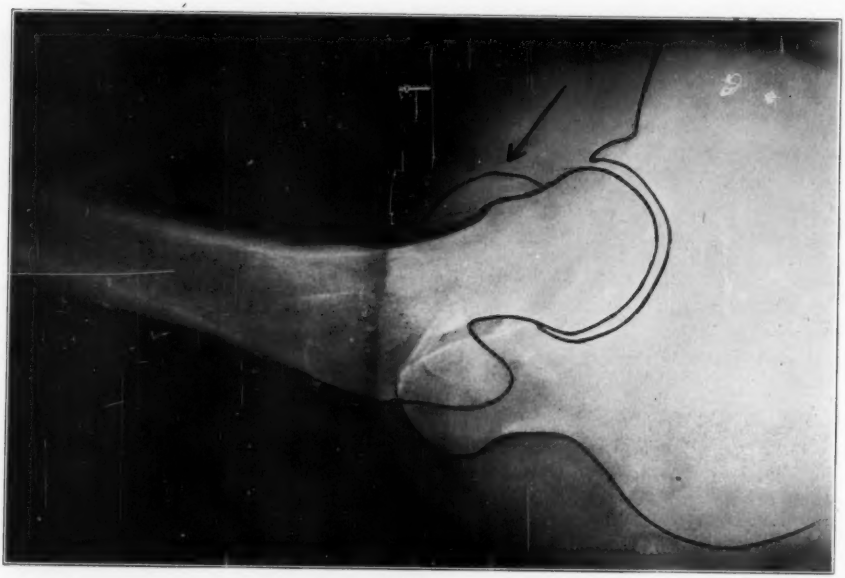

FIG. 3

Intracapsular, detached osseous fragment is seen antero-infero-medially; no acetabular defect can be visualized.

examination a severe scalp laceration was found, together with signs of cerebral concussion. The right lower extremity was held in 20 degrees of abduction and 90 degrees of flexion at the hip joint. The greater trochanter could be felt, high on the posterior crest of the ilium, and all movements of the right hip were painful. There was a severely lacerated, compound fracture of the right patella with wide separation of the fragments.

A diagnosis of posterior dislocation of the right hip was confirmed by roentgenogram (Fig. 1), which, however, was insufficiently good to show the bony detail of the femoral head. Reduction was difficult, but was finally accomplished, with the patient under intravenous pentothal anaesthesia, by direct, forceful traction with the hip flexed to 90 degrees. Because of the cerebral injury and shock, for which two units each of plasma and blood were given, the patella and scalp injuries were repaired under local infiltration anaesthesia. A wire suture approximated the patellar fragments, and the knee was immobilized with a massive Schanz dressing. The hip was partially immobilized by binding the lower extremities together. Convalescence was uneventful; the wounds healed *per primam*.

Roentgenograms, taken one week after admission (Fig. 2) confirmed the reduction of the femoral head, but also showed a free fragment of bone within the joint capsule. At first this was interpreted as a fracture of the posterior lip of the acetabulum; but when further studies, including stereoscopic views, showed the fragment to be lying anterior and infero-medial to the head and neck of the femur, it was decided that the loose fragment had been detached from the head of the femur and not from the acetabulum.

Although there was a good range of painless motion in the hip, the hip was explored, three weeks after injury, through an anterior approach. A large fragment of the femoral head from the articular surface of the antero-inferior portion, with a small ridge of adjacent

FIG. 4

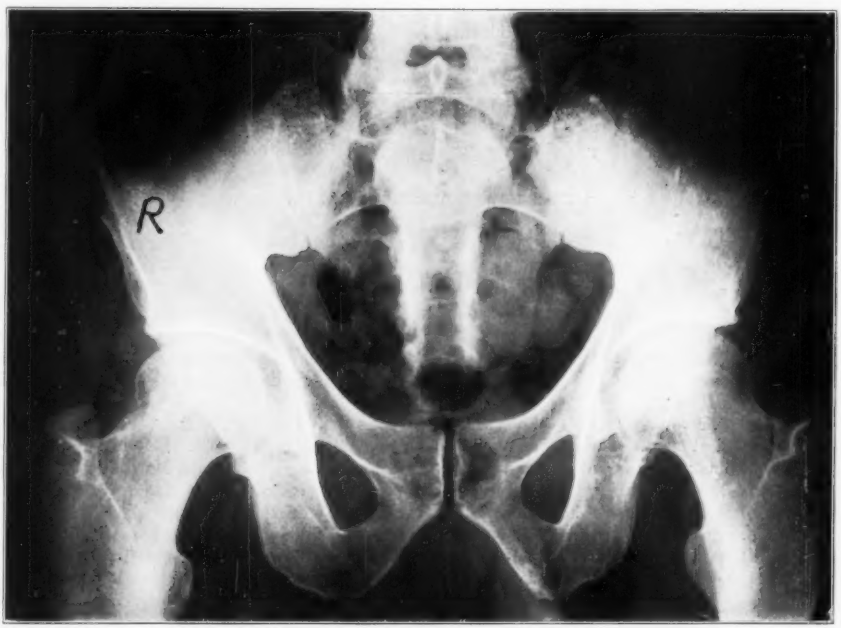

FIG. 5

Fig. 4: Specimen of detached fragment from antero-inferior surface of head of femur, with small portion of adjoining neck. (Artifacts of articular surface from instrument handling.)

Fig. 5: Two years after injury, no avascular necrosis of head of femur is visible. Sclerosis of inferior rim of acetabulum may be seen.

cervical bone attached, was found tightly wedged beneath the joint capsule on the anterior aspect of the neck, joined to the neck by a synovial reflection. This was removed, with another smaller fragment of loose articular cartilage (Fig. 4). The defect in the antero-inferior portion of the head was visualized, but was not disturbed. No fracture of the acetabular rim could be noted.

Traction of fourteen pounds was applied through a Steinmann pin, placed in the supracondylar region of the femur, and was continued for six weeks. This allowed early motion in the injured knee, which the patient soon was able to flex to 150 degrees. Active physical therapy, including heat, massage, and active and passive exercises to both the knee and hip, resulted in continued improvement. The patient was allowed up on crutches eleven weeks after injury, with an elevated shoe on the uninjured side to prevent weight-bearing. At that time hip motion consisted of flexion to 95 degrees, extension to 185 degrees, abduction to 25 degrees, adduction to 40 degrees, internal rotation to 20 degrees, and external rotation to 35 degrees. Roentgenograms of the hip showed a normal outline of the femoral head, except for slight fuzziness of the antero-inferior portion.

One month later, there was a complete range of painless motion in the hip. The patient was very cooperative in the use of his crutches; apparently there was no weight-bearing on the affected side. Weight-bearing was avoided for six months following injury, in the hope that adequate fibrocartilage might form over the denuded portion and that deformity of the femoral head from possible aseptic necrosis might be prevented. Partial weight-bearing was then instituted, and the crutches were discarded two weeks later. At that time the patient had no difficulty in using the right hip, and was able to return to his work at dry cleaning. Three months later, he had a full range of painless motion in the hip; he walked without a limp; and was able to do a full day's work without fatigue. Roentgenograms revealed the defect in the femoral head, but otherwise an essentially normal hip joint.

The patient returned to the clinic on May 25, 1948, two years after injury, walking with a normal gait and with no complaints. Examination showed no shortening of the right lower extremity and a normal range of motion in the hip, without pain. Motion in the right knee had improved almost to normal. Roentgenograms of the right hip suggested the possibility of a slightly superior position of the acetabulum (Fig. 5), but otherwise essentially no change from the previous examination of February 11, 1947.

By questionnaire in March 1949, the patient reported that he had a complete range of motion in the right hip as compared to the left, no limp, almost complete motion in the right knee, and no pain with weight-bearing or walking. He was able to do a full day's work without difficulty, and expressed the opinion that the hip was as good as it had been before the accident.

DISCUSSION

Vitallium-Cup Arthroplasty of the Hip Joint

(*Continued from page 868*)

efficient. In order to bring this about, we must reconstruct both sides of the joint. For this reason, the anterior approach, which gives access to the acetabulum, was developed. Dr. Gibson does not believe in this and has shown illustrations to demonstrate his point. In conditions, such as malum coxae senilis, with overgrowth of bone on the acetabular side as well as a large femoral head, the posterior approach would be very disappointing and certainly not so easy as it appears to be in the film demonstrating the operation. Reconstruction of the acetabulum must be done if we aim to lay the foundation for a joint that will function well permanently.

Dr. Gibson made a statement that the cup should not rock on the head. The cup should rock on the head; it is not physiological for the head of the femur to be encased snugly in the mold. There must be motion between the acetabulum and the mold, and between the femoral head and the mold. If the cup fits snugly and does not rock, we will have motion between the mold and the acetabulum only. A tightly fitting mold interferes with the circulation to the head and neck and, in the course of time, degenerative changes take place inside the mold, resulting in a distorted relationship between the mold and the adjacent structures.

I am glad that Dr. Gibson emphasized the need of careful postoperative treatment. This is most important if the best possible results are to be obtained.

Dr. Alexander Gibson (closing): The cases in this series were essentially cases of osteo-arthritis of the hip. We had one or two other conditions, such as a shallow acetabulum, which in my experience has not been treated successfully. It would demand a degree of excavation of the acetabulum that we have not done.

In regard to the point brought up by Dr. Smith-Petersen, when I said "rocking" I meant no movement from side to side. The joint must never be stiff. It has been our experience that the cup itself sinks into the bone and that the bulk of the movement is between the stump of the neck and the cup.

SURGICAL APPROACH TO THE VERTEBRAL BODY

BY ARTHUR A. MICHELE, M.D., AND FREDERICK J. KRUEGER, M.D.,
BROOKLYN, NEW YORK

From the Department of Orthopaedic Surgery of the United States Marine Hospital, Staten Island, New York

Early vertebral lesions in which the pathological changes are confined to the vertebral body present a problem in their diagnosis. The present-day method of basing the diagnosis solely upon the findings of the roentgenologist and the clinical pathologist is not accurate in all instances. Only upon obtaining definite biopsy evidence can a sound diagnosis be made and the appropriate therapy instituted[2]. Needle biopsy of the thoracolumbar vertebrae is not only a blind and dangerous procedure, but frequently yields unreliable and inadequate material for diagnosis. The anterior or abdominal approach to the vertebrae is difficult and hazardous.

Since a safe method for obtaining adequate biopsy material has not been available, vertebral-body lesions have frequently been treated on an empirical basis with antibiotics, roentgen-ray therapy, or spine fusion. Consequently, several methods for penetration of the vertebral body through a posterior spinal approach, for the purpose of obtaining adequate biopsy and culture material, have been devised. By a direct approach to the vertebral body through definite bone channels which can be exposed readily, the selected portions of the body contents are made available for diagnosis and subsequent therapy. The method of choice for penetration of the thoracolumbar vertebral bodies will depend entirely upon the surgeon's dexterity and his familiarity with the anatomy of the structures involved.

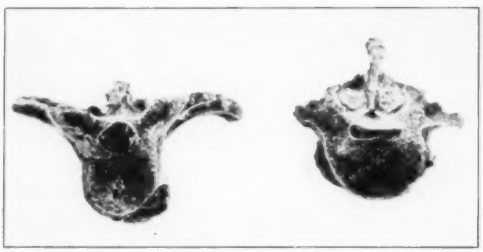

FIG. 1

Transverse sections through the thoracic and lumbar vertebrae show the relative diameter of the pedicle as compared with that of the body.

The transverse diameter of the pedicles in relationship to the bodies of the thoracolumbar vertebrae is of greater proportion than that noted on examination of the mounted skeleton (Fig. 1). A trephine with bores of three-sixteenths of an inch, seven thirty-seconds of an inch, and five-sixteenths of an inch is used for penetration into the body. The gauge used is dependent upon the vertebral body under investigation. The marker is used for locating the centrum of the articular facets, over which the trephine is inserted (Fig. 2).

THORACIC VERTEBRAE

The bodies of the thoracic vertebrae may be approached by either of the two following methods:

Method I

The patient is placed in the prone position. A paravertebral incision is made over the side of the spinous process and over the laminal plate of the affected vertebra. The muscles are retracted and the transverse process is bared. A transverse osteotomy is performed at the base of the transverse process, at its juncture with the laminal plate (Fig. 3,*A*). By depressing or retracting the transverse process from the wound, the isthmus of the vertebra

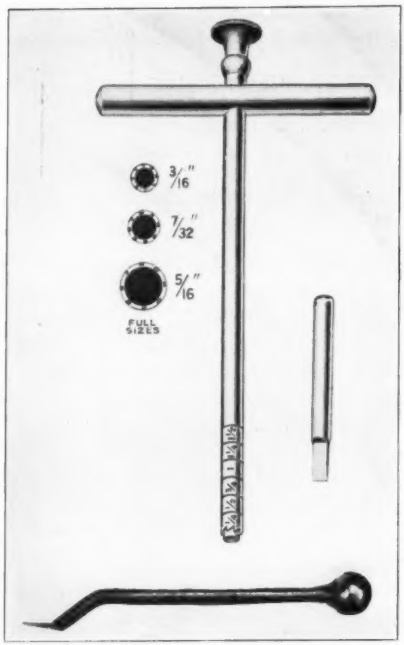

FIG. 2

The trephine with stylet inserted, showing the three diameters. The marker is used for a control in trephining the articular facet.

is exposed and the cancellous nature of its bone structure may be seen. A three-sixteenths-inch trephine with quarter-inch markings is inserted through the fenestra and guided downward with slight pressure, so that a mere twisting action leads the trephine into the pedicle and finally into the body (Fig. 3,*B*). The trephine is removed repeatedly, after minute progressions within the channels have been made. In each instance, the contents should consist of cancellous bone, which indicates the presence of the trephine within the medullary substance of the pedicle. As a result of penetration by the trephine, a channel from the posterior elements directly into the vertebral body is formed, and spongy bone or pathological tissue can be removed readily with a small blunt curette. If he so desires, the operator may use the trephine stylet instead of the trephine, inserting it through the cancellous isthmus into the canal of the pedicle and finally into the vertebral body. Only gentle pressure is required for penetration of the stylet.

Method II

After osteotomy of the base of the transverse process of the involved vertebra has been performed, an alternate method of approach to the vertebral body can be carried out in the following manner: The transverse process is retracted sufficiently, in conjunction with slight depression of the adjacent rib, to expose the junction of the pedicle and body. The trephine is used to penetrate this junction at an angle of 45 degrees toward the centrum, and material is similarly removed with a curette (Fig. 3,*C*).

LUMBAR VERTEBRAE

The approach to the lumbar vertebral bodies is easier than that to the thoracic bodies, both because the vertebrae and their processes are larger and because of the sagittal or anteroposterior arrangement of the facets. Any one of the following three methods may be selected for penetration of the bodies of the lumbar vertebrae:

Method I

A paravertebral incision is made, directly over the articular facet of the vertebral body under consideration. The articular facets are located and denuded. Penetration into the isthmus, pedicle, and body is made through the superior articular process. After this process has been located, the ascending facet will indicate the body of the lumbar vertebra to be operated upon. Towel clips are applied to the ends of the spinous processes of the adjacent vertebrae, and the exposed facet articulation is identified by alternate pushing and pulling on the two clips. A marker is inserted into the joint space of the articular facet and a trephine, five-sixteenths of an inch in diameter, is slipped over the marker (Fig. 4,*A*). The cartilaginous plates of the articular facet are completely gouged when the trephine has penetrated for a distance of one-half inch (Fig. 4,*B*).

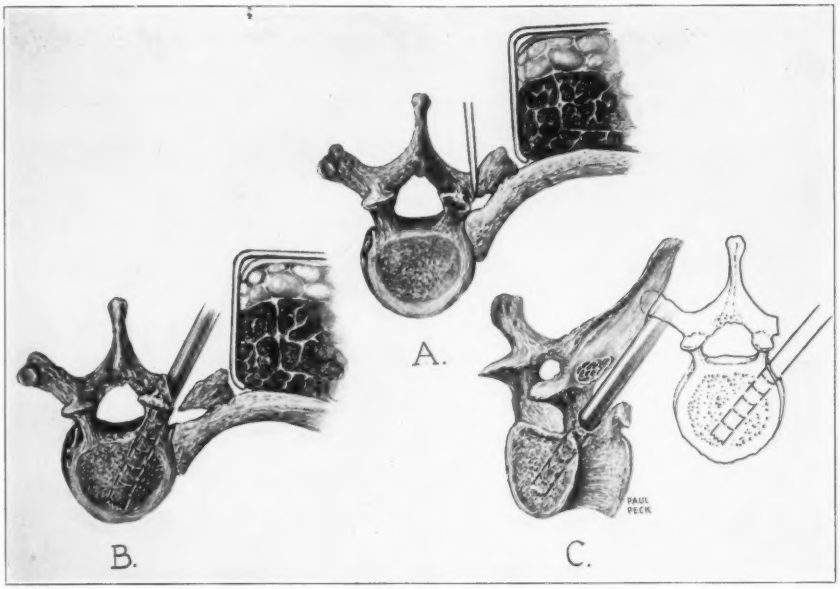

FIG. 3

A: Transverse osteotomy at the base of the thoracic transverse process.
B: Trephine through the fenestra of the isthmus, into the pedicle and body.
C: Trephine inserted into the body, at junction of pedicle.

The two buttons of bone facing the marker are removed (Fig. 4,*1*); the articular cartilage of the apophyseal joint is found to be sandwiched between them. A smaller trephine is inserted into the fenestra and is carried downward, usually by its own weight, for three-quarters of an inch. With slight twisting, the trephine is manipulated within the medullary

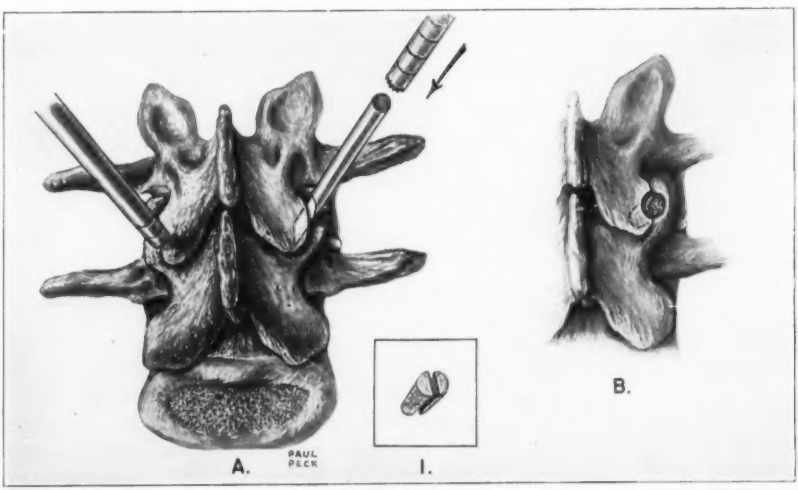

FIG. 4

A: Marker is inserted into the articular facet. Trephine is slipped over the marker.
B: The bored leaves of the articular facet, with a channel of cancellous bone.
1: Inset shows the two buttons of bone removed.

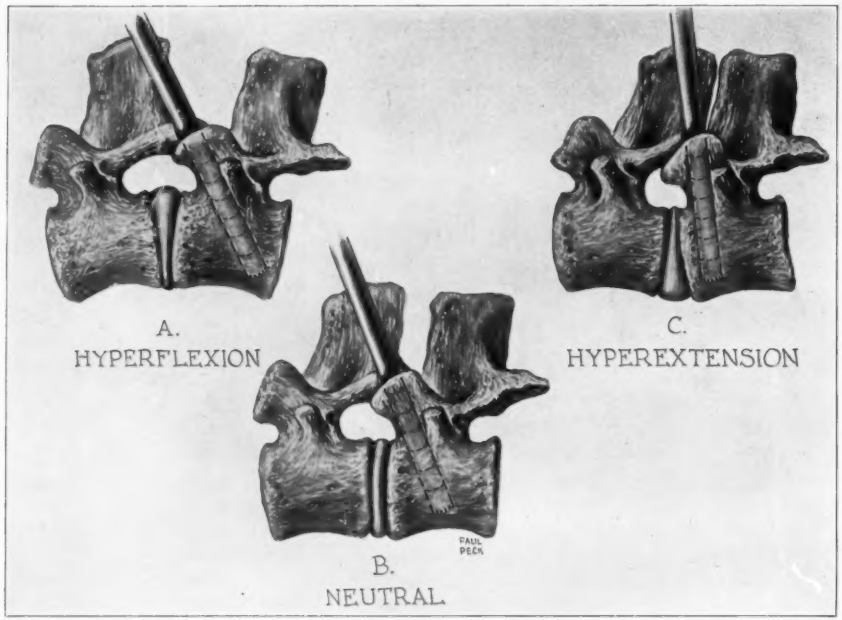

FIG. 5

The position of the spine on the operating table will determine the direction of the trephine.

portion of the pedicle. After each minute progression, the material in the trephine should be examined to be sure that cancellous bone is present. If the cortical bone is being skimmed, the operator can detect this by noting the deflection of the instrument. The body is penetrated in most instances when the trephine has been inserted for one inch. Samples of material for biopsy and cultures can be removed with the trephine through this opening (Fig. 6,*A*). Sufficient material for diagnosis can be obtained by simple curettement of the body. The stylet may be used instead of the trephine for penetration through the fenestra into the isthmus, pedicle, and body. In the lumbar spine, as in the thoracic region, the medullary bone extends within a channel from the isthmus, through the pedicle, and into the body.

After completion of the biopsy, the articular facets [1] are either locked by 90-degree rotation of the removed buttons of bone, or they are reinforced by use of a part of the spinous process, transverse process, or preferably, the iliac bone (Fig. 6,*B*). By inserting a larger trephine through a small incision over the ilium, the necessary peg of bone can be obtained.

Method II

The approach through the transverse processes is carried out by extending the exposure through the articular facet (Method I), and retracting the muscles from the base of the transverse process of the vertebral body involved. An osteotomy is performed at the base of the process, after it has been bared at the posterior surface and the laminal plate has been exposed (Fig. 7,*A*). A greenstick osteotomy of the transverse process is done and it is depressed, but not removed from its bed. A fenestra with exposure of the isthmus is obtained in this manner, and the operation can be continued either by use of a trephine through the isthmus into the pedicle and the body, or by penetration with the trephine stylet (Fig. 7,*B*). Curettement of the body can then be carried out.

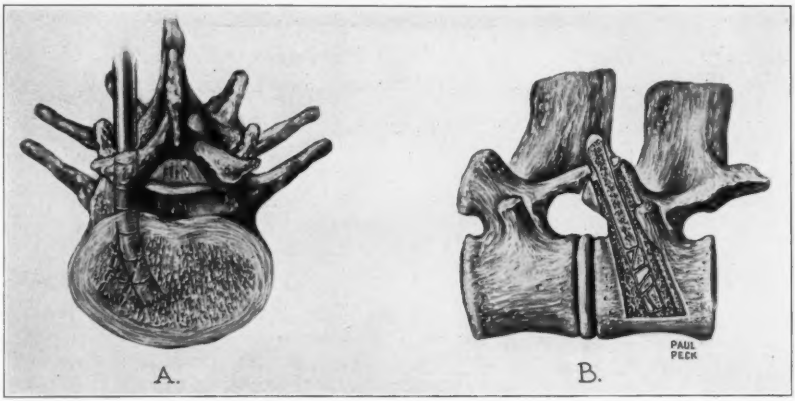

FIG. 6

A: The curved trephine is used to indicate the circumference of penetration of the body by the curette.
B: Iliac bone graft, used to reinforce the articular facets, is fixed into the pedicle.

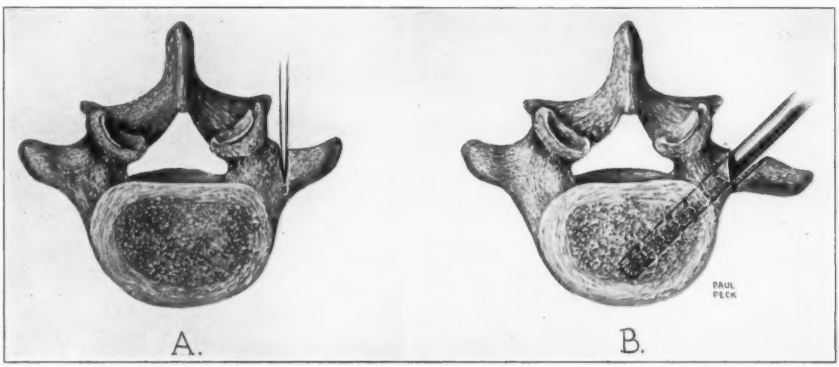

FIG. 7

A: Greenstick transverse osteotomy of lumbar transverse process.
B: Trephine inserted into the fenestra, pedicle, and body.

Method III

This method is in reality a continuation of Method II. The osteotomy is performed at the base of the transverse process of the involved vertebra. The transverse process is not removed from its bed, but is merely depressed; so that, by blunt periosteal stripping, the entire pedicle can be exposed at its lateral margin. The point of junction of the pedicle and the body of the vertebra is selected as the site of penetration of the trephine into the body.

SUMMARY

Five methods of direct approach to the thoracic and lumbar vertebral bodies have been presented. In each instance, the surgeon should select that procedure which is safest for the particular vertebral body involved. By approaching the vertebral body directly through definite bone channels which can be readily exposed, the selected portions of the body contents are made available for diagnosis and subsequent therapy. These methods are particularly valuable in those cases in which the lesion is confined to the vertebral

body, and no other sources of biopsy or culture material are available upon which to base a diagnosis. Moreover, the direct approach facilitates the introduction of penicillin, streptomycin, or other medication into the vertebral body.

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POSTERIOR DISLOCATION OF THE STERNOCLAVICULAR JOINT

REPORT OF A CASE

BY WALTER A. GUNTHER, M.D., KNOXVILLE, TENNESSEE

From the Penn Clinic, Knoxville

Dislocation of the clavicle at its sternal end is relatively rare, as compared with acromioclavicular dislocation. Of the three main types—anterior, superior, and posterior—the anterior is by far the most common. Not more than thirty cases of the retrosternal variety have been reported in the literature.

FIG. 1

Oblique view of left sternoclavicular joint before reduction.

The following report presents a case treated successfully by manipulative reduction.

A fifteen-year-old white American boy reported to the emergency room of the hospital on November 13, 1948, complaining of pain in the chest. He walked slightly hunched over, and held the left forearm in his right hand. Although in pain, he was not dyspnoeic or particularly apprehensive. He stated that two hours

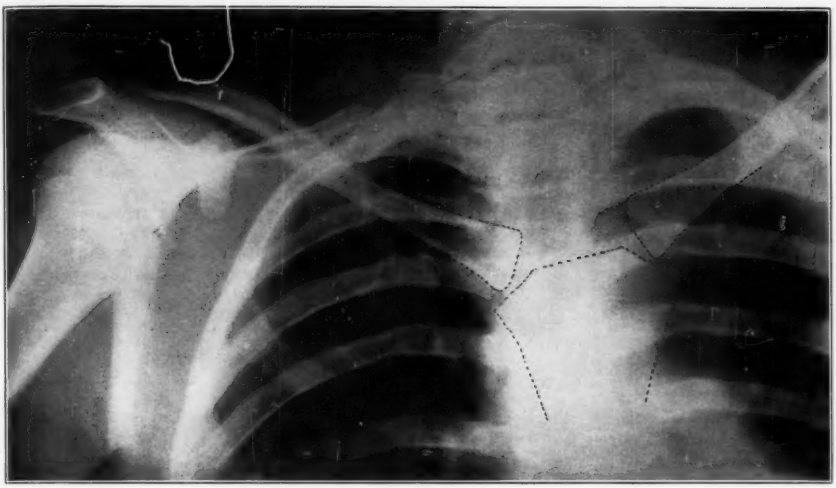

FIG. 2

Oblique view after reduction.

earlier, while engaged in a sand-lot football game, he had hurled his 135 pounds at an opponent of 190 pounds in a "body block". At the moment of impact he had turned the left shoulder toward the opposing player and had received the full force of the latter's charge on the posterior and lateral aspects of his left shoulder. He was knocked to the ground and felt instant pain in the region of the sternum.

On physical examination, a depression was felt at the sternal end of the left clavicle, at the spot where the slightly bulbous end of the clavicle may usually be palpated. There was some swelling over this point and it was extremely tender to the touch. There was no evidence of dyspnoea or dysphagia. No abnormal discoloration was present, nor evidence of air under the skin. Examination of the left upper extremity revealed no signs of peripheral-nerve damage or of circulatory changes. Roentgenograms of the chest wall in right and left oblique views showed the sternal end of the left clavicle to be displaced behind the sternum. The actual overlap, without compensation for distortion in the film, was seven-eighths of an inch.

The patient was told that closed reduction of the dislocation should be done without delay. He refused treatment and left the hospital, carrying the left arm in a sling. Two days later he reappeared, the pain and swelling in this region having increased.

After suitable preparation, intravenous pentothal was administered, and an unsuccessful effort was made to reduce the dislocation by strong upward and outward traction on the left arm, as well as backward pressure on the shoulder. The anterior aspect of the chest wall was then prepared as for surgery, and the points of a towel clamp were introduced through the skin at the left sternoclavicular joint. The clavicle was seized firmly, as close to the sternal end as possible. Strong traction was made on the clamp, while the previous manipulations were repeated by assistants. With a click, the clavicle moved back into its normal relationship to the sternum. Roentgenograms (Fig. 2) showed that the right and left sides were symmetrical. The sternal end of the clavicle could be palpated in its proper position.

While both shoulders were held back, a well-padded plaster-of-Paris figure-of-eight dressing was applied to the shoulder girdle. The boy wore this for one month, and was ambulatory. At the end of that time the swelling had subsided, and the bony landmarks were normal in position and painless to palpation. He had full motion of the left shoulder joint.

News Notes

The American Orthopaedic Association will hold its Annual Meeting at Virginia Beach, Virginia, May 23, 24, 25, and 26, 1950.

The Seventeenth Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held in New York City, February 11–16, 1950, with headquarters at the Waldorf-Astoria.

The Seventy-seventh Annual Meeting of the **American Public Health Association** will be held in New York City, October 24–28. Meetings of related organizations will take place concurrently. The Hotels Statler and New Yorker are joint headquarters.

"Achieving Goals for the Handicapped" will be the theme of the Annual Convention of the **National Society for Crippled Children and Adults,** to be held November 7, 8, 9, and 10, at the Hotel Commodore in New York.

Alpha Chi Omega, national women's sorority, has voted an additional grant of $10,000 to the **National Society for Crippled Children and Adults,** to continue a jointly sponsored scholarship program for training much needed professional personnel to work with the cerebral palsied. The $10,000, in addition to $15,000 already granted, will aid greatly in carrying the program through the next two years.

Since the first awards were made in 1948, more than twenty-five scholarship grants have been provided to qualified physicians, physical therapists, and other specialists. When they have completed their scholarship study, these professional workers assist the National Society's 2,000 state and local units throughout the United States, Hawaii, and Alaska, as well as other public and private agencies, in providing increased services for individuals with cerebral palsy.

On July 6, 1949, a Testimonial Dinner was given to Dr. Leo Mayer, President of the **Federation of the Handicapped,** in honor of his sixty-fifth birthday, by his grateful friends and patients who have established the Dr. Leo Mayer Endowment Fund to perpetuate his work through the Federation, in establishing an institution where the handicapped are employed in a work-training program, are paid a wage, and produce merchandise which is sold nation-wide. The Federation is a rehabilitation agency where professional guidance is given and physical therapy practised under actual working conditions. Jobs are found for those who are made ready for them. Socially, regular entertainments, educational lectures, hobby clubs, and forums are conducted. In a word, the Federation provides a complete and thoroughly up-to-date rehabilitation program. Dr. Mayer has for the past five years served as President of the Federation.

The National Council of the **Kappa Delta Sorority** has inaugurated a prize of one thousand dollars, to be given annually by **The American Academy of Orthopaedic Surgeons,** for the best research in orthopaedic surgery, performed during the year by an individual in the United States. The first award, for the year 1949, will be announced at the Seventeenth Annual Meeting of the Academy in New York, February 11, 1950. Those wishing to compete for this prize may secure further information from the Chairman of the Award Committee for 1949, Dr. Walter Stuck, 1426 Nix Professional Building, San Antonio, Texas.

LETTER TO THE EDITOR

Orthopaedic surgeons who have bone banks available realize the tremendous advantage of obtaining suitable fresh cadaver material. To obtain the consent for this, one must carry out an educational program. A plan has been well worked out at a national level by the ophthalmologists in setting up eye banks.

In many ways the cooperation of the institutions having bone banks may prove of inestimable value. An explanatory pamphlet could be published and distributed. A uniform consent blank could be used. Developments of technique could be shared.

Walter P. Blount, M.D.
324 East Wisconsin Avenue
Milwaukee 2, Wisconsin

Book Reviews

ESSENTIALS OF ORTHOPAEDICS. Philip Wiles, M.S.(Lond.), F.R.C.S.(Eng.), F.A.C.S. London, J. and A. Churchill, Ltd., 42 shillings net; Philadelphia, The Blakiston Company, 1949. $10.00.

In this outstanding volume of 475 pages, Mr. Wiles has concisely and clearly explained the present-day concepts of "the physiological and pathological basis of orthopaedics" and their "application to diagnosis and treatment".

The book offers the graduate who is entering upon his surgical training, the undergraduate who requires classified information, and the general practitioner a ready means of finding himself in the vast field of orthopaedic surgery and of proceeding with his work with assurance that he has a sound foundation upon which to build. To teachers of orthopaedics the book will be invaluable. More than these, the mature surgeon may find in the *Essentials* much that will enable him to revise and broaden his viewpoint.

Logically, the first chapter is devoted to general considerations of the mechanics underlying the functions of the weight-bearing joints. The effects of postural and mechanical faults are stressed, and the importance of strain is thus emphasized at the outset. In the ensuing chapters the arrangement is regional to assist the student with diagnosis and to meet his need for information on pathology and treatment, classified in an orderly manner. Treatment requiring less highly specialized knowledge is described in detail; operative and other methods are given only in general terms. The importance of the patient's cooperation is stressed throughout, and prognosis is discussed. Separate chapters are devoted to "Pyogenic Infection", "Tuberculosis", "Chronic Arthritis", "Tumours of Bone", "Diseases and Congenital Defects of Bone", and "Diseases of the Nervous System".

While the essentials have been presented largely from the British viewpoint, the author has drawn freely from practices in other countries. This is especially true of American methods, from which he seems to have, in most instances, selected the best.

The book reflects the high standards maintained in British publishing. The author's presentation of the subject is thorough-going, but always concise and practical. The book in every way fulfills its high purpose and should long enjoy wide acceptance. The excellent illustrations include seven color plates and 365 text figures.

INSTRUCTIONAL COURSE LECTURES. The American Academy of Orthopaedic Surgeons. Walter P. Blount, M.D., Editor. Ann Arbor, Michigan, J. W. Edwards, 1949. $7.50.

This volume of lectures, given in the Instructional Courses of The American Academy of Orthopaedic Surgeons in 1948, is the fifth in a series begun in 1943. The courses are primarily "refresher", yet the reader of the *Lectures* will find he is kept abreast of the newer developments in the specialty in the wide range of subjects presented. Emphasis is placed on the practical. The subjects covered are those which the Program Committee found to be in greatest demand.

The book is composed of fourteen chapters, each containing one or more carefully edited and comprehensive lectures on the following subjects: "Vascular Tumors of Bone", "Vascular Phenomena", "Plastic and Hand Surgery", "Internal Fixation of Fractures", "Surgical Tuberculosis in Children", "Acute Infectious Hematogenous Osteomyelitis", "Painful Hips in Children", "Practical Foot Problems", "Treatment of Congenital Club Feet", "Surgical Approaches" (to the upper and lower extremities), "Muscle Physiology", "The Surgical Treatment of Poliomyelitis", "Scoliosis", and "Low Back Pain".

As in the preceding years of the Courses, the 1948 faculty is composed of a distinguished group of surgeons who have excellently presented their subjects. The volume is well edited and prepared, for which great credit is due Dr. Blount. The illustrations are profuse and, in general, of good quality. Students, teachers, and practitioners of orthopaedic surgery will find the 1948 *Lectures* of great value.

The preceding volumes of the *Lectures* were edited by Dr. J. E. M. Thomson, who was so largely responsible for the inception and successful development of the Instructional Courses. These volumes reflect much that is important in the development of the art and practice of American orthopaedic surgery during the preceding five years. The first two volumes are in large part directed toward the problems of war-injury and reconstructive surgery; the third and fourth, which are complementary, deal with civilian surgery. Copies of these volumes are also available for those who wish to own the complete set.

THE PARATHYROID GLANDS AND METABOLIC BONE DISEASE. SELECTED STUDIES. Fuller Albright, A.B., M.D., and Edward C. Reifenstein, Jr., A.B., M.D., F.A.C.P. Baltimore, The Williams and Wilkins Company, 1948. $8.00.

Research studies on calcium metabolism, carried out on the Metabolic Ward of the Massachusetts General Hospital during a period of twenty-four years by many different investigators, form the basis of the

material presented by Dr. Albright and Dr. Reifenstein in their outstanding contribution. The advances made by the authors and by those associates, past and present, upon whose studies they have drawn, are presented in a readable style, of sufficient clarity so that the book will be useful to students, yet on the basis of such experience as to make it valuable to physicians, particularly those interested in orthopaedic problems. The text is amplified by many case reports and by excellent photographs, charts, and reproductions of roentgenograms, illustrative of the conditions under consideration.

In addition to chapters on the parathyroid glands, hypoparathyroidism, and hyperparathyroidism, there is discussion of metabolic bone diseases, osteoporosis, osteomalacia, polyostotic fibrous dysplasia, and Paget's disease.

The authors state in their Preface: ". . . we are not content merely to present data; we attempt, where possible, to develop an hypothesis upon which to hang the observations. The hypotheses—it almost follows—are subject to change without notice." Thus not only does the reader have a presentation based upon work of exceptional value, but he is given the mental stimulation of an approach which invites interest in an ever-broadening field.

SURGERY OF THE HAND. Ed. 2. Sterling Bunnell, M.D. Philadelphia, J. B. Lippincott Company, 1949. $16.00.

Surgery of the Hand, published in 1944, received high praise as a book of outstanding value. Dr. Bunnell has now revised and rewritten this book, incorporating his experience during the past five years.

Changes have been made in many chapters. The author has developed many ingenious splints, and these are included in the section under "Active Splinting". New sections have been added in the chapters "Skin and Flexion Contractures", "Bones", and "Joints". A new section on "Occupational Therapy for Crippled Hands" has been included.

However, the greatest changes in the new edition are in Part Three, in the chapters on "Injuries of the Hand", and "Infections of the Hand". The many developments in the field of reconstructive surgery of the hand are reflected in this new book.

As Consultant in Hand Surgery to the Surgeon General of the United States Army, Dr. Bunnell was closely in touch with the Hand Service in each of nine Army General Hospitals. Through these various Hospitals, he had opportunity to watch the reconstruction of about 20,000 hands. The experience in these Army Hospitals is shared with the readers of this new edition through the conclusions which he has reached as to the procedures to be followed in the treatment of injured hands. His definite convictions as to the methods of choice in various conditions are presented from the point of view of a teacher who has had unusual experiences which he wishes to share with his students and those who have had fewer opportunities to perfect themselves in this field of surgery.

As the interest in surgery of the hand has increased in the last few years, particularly through the formation of the American Society for Surgery of the Hand, of which Dr. Bunnell was the first President, many surgeons have been called upon to treat hand injuries.

Dr. Bunnell's book will prove a valuable reference to all surgeons confronted with hand conditions, in the treatment of which so great care in the selection of the best procedure is required.

The book is attractively presented; the illustrations are excellent. It is a book which most surgeons will wish to own.

FUSS UND BEIN. IHRE ERKRANKUNGEN UND DEREN BEHANDLUNG (Affections of the Foot and Leg and Their Treatment). 4 Auflage. Prof. Georg Hohmann. München, J. F. Bergmann, 1948.

This new edition of the well-known text by Professor Hohmann will be welcomed by those who have used earlier editions, as well as by those who have only indirectly known its worth.

The first edition of this book appeared in 1923, and this, as well as the two editions which followed, were dedicated by the author to his teacher in orthopaedic surgery, Geheimrat Fritz Lange. Recognizing the importance of his instruction in the natural sciences, in languages, and in other subjects preparatory to his profession, as well as the contribution of other branches of medicine to his special field, he has dedicated this fourth edition to his teachers, among whom Fritz Lange holds first place.

Beginning with the form, structure, and function of the normal foot, the author takes up the various deviations from the normal,—congenital and acquired deformities of the lower extremity, their etiology, prevention, and treatment; as well as diseases affecting the joints, nerves, muscles, and bones, their diagnosis and treatment, and their possible effect on the function of the extremity. Trauma is also discussed, especially injuries received in sports.

The excellent bibliography, classified under the different affections discussed, will be helpful to those who wish to locate the earlier references to these various conditions. It contains only a few references to articles appearing during the War, and obviously was prepared before the author had access to the British and American literature of the past ten years.

This book contains more than twice the number of text pages of the earlier editions. The number of il-

lustrations has been increased to 450 and they are more attractively presented than in the previous editions. Both author and publisher are to be congratulated upon this revision, made at a time when its preparation must have been attended with great difficulties.

BRITISH SURGICAL PRACTICE. Volume 5. Edited by Sir Ernest Rock Carling, F.R.C.S., F.R.C.P., and J. Paterson Ross, M.S., F.R.C.S. London, Butterworth and Company, Ltd., 60 shillings (25 pounds for the set); St. Louis, C. V. Mosby Company, 1948. $15.00 ($125.00 for the set).

The Editors of *British Surgical Practice*, who have been releasing units of this eight-volume set at intervals since the first number appeared, late in 1947, have now completed Volume 5. Proceeding with the established alphabetical arrangement, this work begins with Hodgkin's disease and concludes with lymphogranuloma inguinale. In this portion of the alphabet are contained material on injuries and many sections dealing with joint disorders, including caisson disease, acute infections of the joints, internal derangements of the knee joint, and joint tuberculosis. Thus the present volume is of special interest to orthopaedic surgeons.

Each volume in the series follows the same general pattern so that, for most conditions, the etiology, anatomy, pathological findings, clinical picture, differential diagnosis, treatment, results, and prognosis are presented. Each section has been carefully prepared by an authoritative worker in the field, and the series is living up to its early promise of being a valuable aid to the surgeon.

HOSPITAL TRENDS AND DEVELOPMENTS, 1940 TO 1946. Edited by Arthur C. Bachmeyer, M.D., and Gerhard Hartman, Ph.D. New York, The Commonwealth Fund, 1948. $5.50.

This book is a composite reflection of numerous writers in the hospital and public-health field, given cohesion and form by arrangement according to the various phases of an administrator's activities and interests. (Incidentally, mention of hospitals and public health together is itself an expression of one trend.) The authors' principal problems were to decide what the trends and noteworthy developments were and to select the articles in which they are set forth most clearly. Presumably they also exercised the editorial blue pencil here and there, but so skillfully that the marks do not show.

They have done their work well. This could have been anticipated, as Dr. Bachmeyer is dean of the hospital administrators in the Chicago region, while Dr. Hartman is developing his skill as an administrator upon a background of several years of educational activity as Secretary of the American College of Hospital Administrators.

Just what interest bone and joint surgeons will take in a book of this character is not clear, except that they all need hospitals in which to operate. There may be a few, however, who would like to get some of the background of today's most argued medical question as it applies to hospitals. This comes in the first part of the book. The rest will probably be attractive mostly to hospital administrators, for whom the book was really intended. Students of this specialty will find it interesting and instructive, a good adjunct to their seminars and field trips. Practitioners are likely to find some of the articles familiar, but they are worth reading again. There is a chance of discovering some things not seen before, as the authors have gleaned beyond the field ordinarily reaped by a reader of strictly hospital publications.

As the title suggests, this is, for the most part, a series of explanations, discussions, and advice, rather than the sort of detailed direction for setting up departments and putting them into operation which made Dr. MacEachern's textbook so useful. However, most of the things a hospital administrator does and thinks about in his multiple role of architect, accountant, attorney, clergyman, credit expert, economist, educator, engineer, laundryman, publicist, restauranteur, crystal gazer, and sometimes physician, are represented by at least one article.

As samples, take this reviewer's favorite exposition of the proper duties and the value of a medical social-service department, the discussion of work suitable for nurse aides, and the late Dr. Joe Clemmons' account of how he saved the Roosevelt Hospital a lot of money by doing over his laundry with new machinery. This array of writers exhibit many styles with only the fictional narrative form missing, but each of them has treated his subject with the care that only personal interest in it could produce.

A book of this kind should not be read rapidly. He who takes it a little at a time, stopping to digest each bite before taking the next, will find himself nourished and sustained.

DEEP MASSAGE AND MANIPULATION ILLUSTRATED. Ed. 3. James Cyriax, M.D., B.Ch. (Cantab.). London, Hamish Hamilton, Ltd., 17 shillings, 6 pence; New York, Paul B. Hoeber, Inc., 1948. $5.00.

This book is written to instruct student and graduate physical therapists in the technique of massage. The type of massage described is considered more or less specific for the condition commonly known as "fibrositis". Photographs show the position of the patient and of the therapist's hands for each area of the body. The description accompanying each plate serves as a detailed prescription for the technician.

Most physiatrists in this country would doubtless emphasize the combined use of other agents in their prescriptions, such as heat in various forms and active exercise. The amount of pressure, the range of movement, and the duration of the treatment are still only approximately indicated, and are part of the art of physical therapy. Physicians should be interested in these methods of treatment and will be intrigued by the good results almost uniformly reported. Acceptance of the diagnosis of "fibromyositis" is essential for utilization of these procedures.

Those familiar with the previous edition of this book will find little change other than a few more photographs; these are uniformly of good quality, as is the type and paper.

FRACTURES AND ORTHOPAEDIC SURGERY FOR NURSES AND MASSEUSES. Ed. 2. Arthur Naylor, Ch.M., M.B., M.Sc. (Sheff.), F.R.C.S. (Eng.), F.R.C.S. (Edin.). Edinburgh, E. and S. Livingstone, Ltd., 17 shillings, 6 pence; Baltimore, The Williams and Wilkins Company, 1948. $5.00.

This book of 296 pages, divided into fourteen short chapters, is intended to introduce nurses and masseuses to the more common fractures and orthopaedic conditions. It is brief and concise, and contains many illustrations of apparatus, instruments, techniques, and clinical cases which would be helpful for students and nurses.

This publication, however, does not differ from the many small textbooks on fractures and orthopaedic conditions which have preceded it. As its readers will be chiefly nurses and masseuses, the approach to fractures and orthopaedic problems is presented from their point of view. However, the book could have been made more useful to nurses by placing more emphasis upon specific problems of nursing care, and to masseuses by more detailed instruction in the problem of rehabilitation as related to each type of injury. Space is allotted for this, but it seems inadequate for a book of its type.

The reader will receive a general, but limited, review of the recognition and treatment of orthopaedic conditions and fractures.

FINAL RESULTS OF OSTEOSYNTHESIS OF FRACTURES OF THE FEMORAL NECK AD MODUM SVEN JOHANSSON. A STUDY OF A TEN-YEAR MATERIAL. Gunnar Odén. *Acta Chirurgica Scandinavica*, **96**: Supplementum 131, 1947.

The author analyzes the results of treatment of 314 fractures of the upper portion of the femur, using a cannulated Smith-Petersen nail, inserted as fixation with roentgenographic control. This group comprises 59 per cent. of all upper femoral fractures treated at the Sahlgren Hospital, Gothenburg, from 1932 to 1941. They represent a thorough reinvestigation of the results obtained by Sven Johansson.

The 314 fractures of the femoral neck were distributed as follows: 248 varus fractures; 44 valgus fractures; 18 intertrochanteric fractures; and 4 pertrochanteric fractures.

Traction, with the affected leg in external rotation and extension, was used for about a week before operation. Local anaesthesia with ether was used generally and, in most cases, reduction was achieved by simple internal rotation just before fixation. When difficulty of reduction was encountered, ordinary traction was resumed for a week or so, and repeated attempts at manipulative reductions were avoided. There was a mortality of 8 per cent.

Most of the patients were kept in bed for four weeks after operation. Redislocation after reduction occurred in 66 of the 314 cases. A follow-up study of the whole group was not possible; but, from his study of those cases available, the author inferred that valgus fractures heal easily, and that, among varus fractures, those fixed in valgus are least likely to lose position, and those fixed in varus are most likely to lose position.

Odén felt that, in addition to the circumstance of position of fixation, technical deficiencies of the operative procedure were most important in producing loss of position, and that early weight-bearing was not the cause of loss of position.

Re-nailing was done in thirty-eight cases. Of those available for follow-up, non-union, loss of position, and head necrosis were much more frequent than in the entire group. Bone-grafting with re-nailing was employed only twice, and each time *un*successfully.

Of the whole group, 144 neck fractures were submitted to re-examination at least three years after nailing. Seventy per cent. were considered to have had good results; 10 per cent. were "less good"; and 20 per cent. were bad.

Pseudarthrosis occurred in 10.8 per cent. Some head necrosis was present in 38.4 per cent., with joint deformity in nine out of ten of these; 24.7 per cent. had neck resorption. Slipping of the nail was evident in 44 per cent.

The author considered that necrosis of the head, the most frequent cause of bad results, was a vascular phenomenon not influenced by the presence of a metal nail. Swedish stainless-steel nails, used during the latter five years of the period, were non-corrosive and satisfactorily strong.

The observation was made that symptoms from arthrosis following head necrosis often diminished greatly after two or three years.

AFFECTIONS MÉDICALES ET CHIRURGICALES DU PIED. Raphaël Massart. Paris, G. Doin et Cie, 1948. 470 francs.

The author's intention to give a simple description of lesions of the foot, mainly for general practitioners, is well accomplished in this 150-page book with forty-four drawings. Each of its thirteen chapters contains a complete and vivid description of foot conditions.

The author should particularly be commended for allotting considerable space to "minor", but important, foot problems, such as corns and plantar warts. His painstaking description of the corn, however, fails to bring out the importance of the bony prominence superficial to which the corn usually is formed. Consequently, smoothening of the bone by removal of these prominences with primary closure of the wound would seem to be preferable to the incision over the corn down to the bone which he leaves open to granulate.

Calcaneal spurs are blamed for symptoms in painful heel, although the author admits the existence of painful heel due to some "mysterious cause" without the presence of spur. His emphasis upon the removal of spurs may be somewhat too radical, as the majority of these cases are relieved by padding and plates.

Intermittent claudication, one of the most important diagnostic features of arterial occlusion, is not mentioned. He speaks only of gangrene of three types: (1) endarteritis sclerotica, (2) thrombo-angiitis obliterans, and (3) diabetic endarteritis, without stating that in the majority of these cases the course is quite benign without even the formation of an ulceration.

Congenital division and fracture of the sesamoids of the big toe are not differentiated, and removal of the sesamoids advocated by the author may be avoided in most cases.

The author is justly opposed to the Hueter-Mayo operation for hallux valgus, as it deprives the foot of its important medial weight-bearing point. He advocates Hohman's type of wedge resection of the first metatarsal neck, combined with passing a strip of fascia lata surrounding in garter-like fashion the metatarsal necks. This operation he performs in two stages.

Similar passing of the fascia lata or a kangaroo tendon around the metatarsal necks is advised as the best procedure for treatment of Morton's type of neuralgia. The existence of plantar neuroma, described by American authors, is mentioned simply in a footnote.

Club-foot is held to be a consequence of a vicious position in the uterus. Gradual manipulation without anaesthesia, or *redressement forcé* with anaesthesia, both followed by immobilization, have given the author good results. He obviously has no knowledge of Kite's method, and mentions Denis Browne splints only in a footnote.

A good morphological description of different forms of flat-foot is given, but no theories as to its etiology are offered. Corrective plaster casts or manipulation under anaesthesia are used, followed by immobilization in plaster, together with general treatment (calcium phosphate, arsenic, and hypophyseal extract). Whitman's type of plates are advised. Among many operative procedures for flat-foot, the author obtains the best results by simply resecting the head of the talus.

In tuberculosis of the talus, early and complete astragalectomy, before the formation of sinuses, is strongly advocated. Tuberculosis of the tarsal bones may be treated conservatively in children; most adults eventually require amputation.

The author has been unable to confirm the good results published in America following fusion of the ankle, with the use of tibial grafts, and is opposed to this method.

In the last chapter, on amputations of the foot, Ricard's operation, consisting of disarticulation through the Chopart line combined with astragalectomy, is preferred to the Syme amputation as it preserves the weight-bearing heel.

On the whole, the book is brief and comprehensive. It reflects a wide and well-digested experience on the part of the author, and should form a significant addition to the libraries of French-speaking general practitioners.

CLINICAL ASPECTS AND TREATMENT OF SURGICAL INFECTIONS. Frank Lamont Meleney, M.D. Philadelphia, W. B. Saunders Company, 1949. $12.00.

This is a fitting companion-piece to the author's *Treatise on Surgical Infections*, published in 1948. The earlier volume dealt with the fundamental principles underlying the entrance and spread of bacteria in the body, and the mechanism of defenses of the body against infection. The present volume deals with the surgical and chemotherapeutic measures which may be utilized to control infection.

The eighteen chapters are arranged to cover infections of every anatomical area, and are illustrated by numerous well-written case reports from the records of the Columbia-Presbyterian Medical Center. There are also 276 well-chosen illustrations. An excellent bibliography follows each chapter.

Dr. Meleney has enlisted the aid of his former residents to cover certain subjects. Thus John S. Lockwood has written the chapter on "Physiological Consideration in Surgical Infection", Harold D. Harvey has contributed the chapter on "Surgical Infection of the Peritoneum", and a chapter on "Surgical Infections in War Wounds" is divided between Alfred B. Longacre and William R. Sandusky.

The treatment exemplified covers both the period before the advent of the sulfonamides and the present. A detailed account of the usefulness of penicillin, streptomycin, and bacitracin is given wherever appro-

priate, and the course of an infection is compared by means of case reports as it occurred with each method of treatment.

This volume contains the latest information on surgical infections, and will probably remain authoritative for an indefinite period of time, subject to newer forms of therapy. No surgeon, general practitioner, or medical library can afford to be without it.

MALADIES DU SQUELETTE (Diseases of the Skeleton). Lucien Leger, R. Ducroquet, et Henry Leger. Paris, Masson et Cie, 1949. 1,200 francs.

The title of the book may suggest a treatise on diseases of the skeleton in general; however, the text actually consists of a few of the important, but less known, entities affecting the skeleton. Albright's syndrome and affections which may be classified in this group; isolated xanthomatoses; lipoid granuloma without cranio-hypophyseal involvement; eosinophilic granuloma of bone; osseous lesions of von Recklinghausen's neurofibromatosis; melorheostosis; Milkman's disease; essential osteolysis; and myeloma are the subjects of this book.

The choice of these pathological entities was not accidental. Although some of them are obviously not interrelated, others have doubtless a common anatomicopathological basis. Thus, alongside the symptomatic group of Hand-Schüller-Christian diseases may be placed the xanthomatoses. Albright's syndrome may, perhaps, be found related to a series of osseous involvements associated with cutaneous dyschromia, presenting a transition to the bone manifestation of von Recklinghausen's neurofibromatosis.

The organization of the book is excellent; it is replete with useful information, many illustrations, and followed-up case histories, and represents a complete, lucid, and live analysis and description of these pathological conditions. It has extensive bibliographical references.

The orthopaedic surgeon who reads French will find it a valuable addition to his library.

SURFACE AND RADIOLOGICAL ANATOMY FOR STUDENTS AND GENERAL PRACTITIONERS. Ed. 3. A. B. Appleton, M.A., M.D.(Cantab.); W. J. Hamilton, M.D., D.Sc., F.R.S.E.; and G. Simon, M.D., B.Ch., D.M.R.E. (Cantab.). Cambridge, England, W. Heffer and Sons, Ltd.; Baltimore, The Williams and Wilkins Company, 1949. $9.00.

In this, the third edition of *Surface and Radiological Anatomy*, the text has been revised and new plates have been introduced to bring the work up to date. The authors have added the roentgenographic approach to the usual study of anatomy. By extensive use of illustrations, they have coordinated roentgenographic anatomy with those features which can be determined by external examination, as well as with the details which can be determined only by dissection. Proper emphasis is placed upon individual, anatomical, functional, and postural variations which alter the position of organs in relation to surface and other landmarks. Thus an excellent contrast is obtained between the living subject and the cadaver.

The text is well arranged and the type is well chosen. The first section deals with "General Anatomy and Methods". Subsequent sections are devoted to "The Upper Limb", "The Chest and Back", "Abdomen", "Head and Neck", "The Vertebral Column", and "The Lower Limb". The Appendix contains tables with data on ossification and on segmental innervation of muscles. A fairly complete index is included.

The text includes brief sketches of bones, muscles, joints, nerves, vessels, and organ-structure relationship and action, with correlation of superficial and roentgenographic landmarks. Interesting techniques are interpreted, and so are hints of occasional pathological processes, to add interest.

The illustrations consist of photographs of live models, frequently coupled with a schematic anatomical dissection or with superimposed diagrams. The descriptive captions are excellent. The terminology is simplified and is that in common usage. The roentgenograms (the authors prefer the term skiagram) are numerous, demonstrating the positions and structures under discussion. The joint studies are excellent, and are correlated with the text through a description of muscle action. Most of the osteology is presented by the roentgenographic method, and includes reference to and illustrations of bone and joint development. Diaphragmatic action is demonstrated, as are the organs which can be outlined by contrast media. This introduces, under suitable headings, examples of interesting roentgenographic techniques, such as tomography, kymography, bronchography with studies of the bronchial and lung divisions, myelography, encephalography, and angiography, as well as the more common roentgenographic diagnostic procedures.

The authors seem a little modest in designating this book "For Students and General Practitioners". Its concise and systematic fashion of presentation makes for easy reference. In the 330 pages are incorporated a mass of related information which could be put to use by most physicians.

CONFERENCE ON POST-GRADUATE EDUCATION IN ORTHOPAEDIC SURGERY*

INTRODUCTORY REMARKS

By A. R. Shands, Jr., M.D., Wilmington, Delaware, *Chairman*

Alfred I. du Pont Institute of the Nemours Foundation

In 1944, The American Academy of Orthopaedic Surgeons and The American Orthopaedic Association appointed a six-man Joint Committee on Post-Graduate Training, with Dr. Ralph K. Ghormley as Chairman. (Members representing The American Academy of Orthopaedic Surgeons are Joseph S. Barr, M.D., Ralph K. Ghormley, M.D., and J. Spencer Speed, M.D. Members representing The American Orthopaedic Association are Fremont A. Chandler, M.D., Paul C. Colonna, M.D., and Philip D. Wilson, M.D.) In 1946, I was added to the Committee as a seventh member and was made its Secretary. The first objective of this Committee was to increase the facilities for orthopaedic training, in order to provide for the medical veteran desiring to become a qualified orthopaedic surgeon. This was accomplished by reviewing the approved training services in the United States, asking that as many of these as possible increase the number of residents, and recommending the establishment of new training services in hospitals and clinics without approved training, but with the necessary facilities and staff.

In two years' time the number of training services was increased from approximately 79 to 238, and the number of residents from 253 to 726. The American Medical Association and The American Board of Orthopaedic Surgery had previously agreed to grant temporary approval to all of the new services recommended for approval by this Joint Committee. In the fall of 1948, twenty-eight orthopaedic surgeons visited these 238 services, reviewed the training, and submitted reports. These reports resulted in the changing of the types of approval of approximately fifty services. Following this review of orthopaedic training, it was decided that the next work of the Committee should be a conference on the methods and types of post-graduate education. The Conference today is the result of this decision.

The last report on residencies in the *Journal of the American Medical Association* for May 14, 1949, lists 257 hospitals with approved training in orthopaedic surgery. These hospitals have 787 available orthopaedic residencies, which are approved as follows: for adult work, 195; for children's work, 110; for fractures, 110; and for basic sciences, 110.

In the survey of 262 hospital services in 1947, information was obtained on the questionnaires (Question 21) concerning the responsibility of the orthopaedic service for fractures, osteomyelitis, et cetera. This information, which has never been published, is thought to be most appropriate to present at this Meeting. It is as follows:

Question 21. *Is the orthopaedic service responsible for:*

	Wholly	Partially	Not at all	Total Answering Question
1. Fresh fractures	198 (83.5%)	35	13	237
2. Acute osteomyelitis and pyogenic arthritis	230 (91%)	18	5	253
3. Soft tissue of extremities	135 (51%)	98	29	262
4. Peripheral-nerve injuries	71 (31%)	65	93	229
5. Acute poliomyelitis	109 (56.4%)	31	53	193
6. Amputations	127 (54.3%)	86	21	234
7. Surgery of the hand	116 (50%)	86	31	233

What is the objective of resident training? It is to create an orthopaedic surgeon: (1) who has surgical skill and judgment,—that is, one who is good with his head as well as his hands; (2) who has a curiosity for the unknown and a desire to improve the known; (3) who has an understanding for the patient as a whole and his restoration to normal or as nearly normal living as possible; (4) who has a full appreciation of where the orthopaedic surgeon fits into the general scheme of medical practice; and (5) who will develop into a leader in his medical community. If this type of orthopaedic specialist is created, the training is well done; and it is the wish of your Chairman that there will develop in the discussions this afternoon the formula for training which will result in just this type of doctor.

There is definitely no one best method of resident training, but there is undoubtedly a better method or an improved method for every training service. Out of this Conference it is hoped will come an improved pattern of training for each of the 257 approved hospital services. At the Conference held last year on Un-

* Conducted at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 18, 1949.

dergraduate Education, Dr. F. H. Arestad of the Council on Medical Education and Hospitals of the American Medical Association stated that, while a model plan can be developed as a guide, "it should not be developed as a fully standardized plan, because you can never really standardize teaching itself". We shall try this afternoon to develop the ideas for a model plan, but definitely with no thought of attempting to standardize this plan. This model plan then can be used by the hospitals and clinics as a guide, in order that the same general pattern of training may be received by all orthopaedic residents.

Before calling on the first speaker, the Chairman wishes to express a word of appreciation to our Board, which has done so much for our present training program. This, through its past President, Dr. Guy A. Caldwell, and its members, has stood for high standards of training. Requirements for training have been laid down, particularly for the basic sciences, which may have seemed to some to be too strict and perhaps unnecessary, but there is no doubt that, although these requirements may have worked a hardship on a few, they have resulted in the best orthopaedic training for the greatest number. This cannot help but result in better orthopaedic practice throughout the nation, and in time to come will create more solid ground for orthopaedic surgeons to stand upon. We all owe a debt of gratitude to our Board for what they have accomplished for the specialty, and I wish to express to the Board particularly the thanks and appreciation of the Post-Graduate Training Committee.

In the preparation of the program, an attempt has been made to have all direct and indirect phases of training presented. We are to hear also from those representing the Board, the American College of Surgeons, and the American Medical Association. It is regretted that time will not permit everyone to speak who has something to add.

A PROGRAM FOR TRAINING IN ADULT ORTHOPAEDIC SURGERY AND FRACTURES

By Alan DeForest Smith, M.D., New York, N. Y.

New York Orthopaedic Hospital

The title implies that the service is limited to adults, but it is preferable when possible to include children, in order that complete training may be given in one institution, without sharply dividing the cases. The organization of the service will depend upon a number of factors, one of which is the size of the hospital. If possible, it is preferable to segregate the fracture cases in separate wards. This facilitates their treatment and leads to better results. The fact that they frequently are emergencies and that special equipment is necessary create special problems which set them somewhat apart from the usual orthopaedic cases. This does not mean that a separate fracture staff is necessary, for in fact it is better that the staff rotate in the care of the two groups.

The minimum period of training for residents in order to satisfy the Board requirements is six months for fractures and one year for adult orthopaedic surgery, but those who wish to limit their training to adults are obliged to spend an additional year on such a service instead of one year with children. This is apt to cause some complication in the organization of the residency. At the New York Orthopaedic Hospital we have a three-year program, which is set up as follows: The first year, the assistant resident is on an orthopaedic service for both adults and children. The second year, six months are devoted to the study of basic sciences and six months to fractures. We purposely have deferred the basic-science period until the second year, because we believe that there then will be a better understanding of what is needed and a better appreciation of the courses. The third year is spent as a fellowship, during three months of which each man is senior resident. For the remainder of the year he works in the Out-Patient Clinic and in the operating room, and attends rounds and conferences.

Thus there are twelve men always in training, with two completing their service each six months. Each man is assured of receiving his minimum of three years of training without the possibility of being dropped at the end of the first or second year, as happens in the pyramidal system, in which one resident serves for a year or more. Opportunity for continued training for those showing unusual aptitude is offered in the form of a limited number of senior fellowships. These fellowships also are of great advantage to the Hospital, in enabling it to obtain the services of men who have had a residency in another hospital and who wish to spend an additional year in this Clinic. We find that the residents bring with them many new ideas, and help to give us a broader point of view.

Education in the resident stage is best carried out by practical instruction at rounds, conferences, staff meetings, and in the operating room and clinic. Some more formal mode of instruction seemed advisable, however, and, after trying various methods, we have decided upon a series of seminars each year, conducted by various members of the staff. These are informal and are carried out by the method of questions and answers, rather than as didactic lectures. The residents and fellows are expected to do some reading in preparation for them and to be prepared to enter intelligently into the discussions.

In addition to somewhat extensive instruction in pathology, given during the basic-science period, pathological conferences are held weekly. During the second year, in addition to the study of the histology of bone tumors, the men attend a weekly bone-tumor clinic at the Memorial Hospital. Regular conferences are held several days a week with the roentgenologist, at which the current films are discussed. Additional practical instruction in roentgenology is given during the basic-science period, and includes positioning of patients.

During the first year the assistant residents attend the out-patient clinics as much as possible; but the major part of this experience is gained during the third year, when they are not restricted as closely by ward responsibilities. We regard this as one of the most important parts of the entire program, and feel that too much time cannot be spent in this phase of the work. In addition to the general clinics, there are special ones dealing with scoliosis, club-foot, arthritis, neurology, and back conditions. Each man, by rotation, participates in these special clinics at some period during his training.

Each man is required during his three-year period to carry out some clinical investigation or research project and to prepare a report, to be read at a staff meeting. Biographical sketches of important figures in the history of orthopaedic surgery are prepared by the members of the resident staff, and usually one is read at each monthly staff meeting. Some excellent papers have been written, which have been stimulating to seniors and juniors alike.

THE IDEAL CURRICULUM IN CHILDREN'S ORTHOPAEDIC SURGERY

By William T. Green, M.D., Boston, Massachusetts

Children's Hospital

The essentials for a training program in children's orthopaedic surgery are:

1. Sufficient diversified representative clinical material;

2. Capable orthopaedic surgeons in the children's field to spend sufficient time in teaching the men who are in training.

The training program must be adapted to local situations, so that an ideal curriculum is difficult to discuss. What would be ideal in one situation would not be ideal in another. However, certain comments may be made regarding an ideal plan of training. I would not, by choice, call it a curriculum, which I do not believe graduate training should be.

In general, I believe that the best type of training represents an evolution from the apprentice system, in which, in effect, the apprenticeship is to a hospital service with all its attendant diversification rather than to one individual. Essentially, the institution should be centered about the problems as they arise on the service. Ordinarily, the problems presented by the patients, singularly and in the aggregate, serve as the axis about which training revolves. Progressive responsibilities and experiences should be given the trainee, as he is ready to receive them. Didactic lectures should be minimal, although, when judiciously used, they may have a place. On the other hand, conferences and exercises in which the trainees participate are valuable, and form an essential part of any program.

Certain specific comments may be made under appropriate headings:

The Hospital in the Training Program

As previously indicated, the first requirement is that the hospital engaged in the training program must have a sufficient number of patients, representing all types of orthopaedic problems at all ages during the period of growth. It should have large out-patient clinics, not only to give experience in the types of problems which are presented in such a clinic, but also to allow continued observation of patients who have been discharged from the in-patient division.

Ideally, a children's orthopaedic service is best located in a hospital which is concerned with all types of pediatric problems, both medical and surgical, although at all times the orthopaedic service must maintain its autonomy. Such a relationship is valuable from the standpoint of consultation with the various services. It is likewise an advantage for the hospital to be a participant in undergraduate teaching and graduate teaching in other specialties. By contact with all divisions, and in particular with the residents in training in other specialties in pediatrics, the trainee develops a breath of approach to the problems of childhood which might otherwise be missed.

Residency Assignments and Rotation

A service employing one resident is at a great disadvantage. This can be compensated for in part by the visiting orthopaedic surgeon spending an inordinate amount of time with each resident in turn. It is preferred to have at least two residents on a junior-senior relationship, both in time of service and experience.

A service that requires a larger number, however, is much more desirable in that it permits a natural succession of duties by the so-called "staggered system" of appointments, and provides for a better discussion group. A large part of the effective teaching of a trainee is by those residents who are senior to him in the rotation.

The timing of the training in children's orthopaedic surgery in relation to the total program may vary. There is much to be said for a rotation through children's orthopaedic surgery at the start of the clinical training. Under such a plan, it is essential to have, in addition, a senior resident or residents on the children's service who have completed at least two years of training. Such senior residents have a teaching function and are prepared to receive senior surgical experience. We prefer to have a chief resident who has completed three years of training and is prepared for a position of great responsibility.

Organization

The organization of the visiting staff or attending surgeons must vary according to local circumstances. It is preferable in most hospitals to have several visiting men who have periods on house service and off service. This gives diversity to the teaching program, but continuity must be maintained by the orthopaedic surgeon-in-chief.

Out-patient clinics should be attended by visiting men who consult and advise. The major activities of the clinics, however, should be performed by the resident staff.

Clinics integrated toward particular conditions are often desirable. They may be assigned to a particular visiting man, who has this as a special interest. Such an arrangement provides for a continuity of care, concentrates thought, and leads to productive activity. It provides an excellent teaching medium.

The organization of the house staff should be such that each man progresses from position to position, each with increasing responsibility. The men in training must do the work; observation has limited value. Surgery in the trainee's mind represents the "cream", and this should be considered in defining the duties of the various positions.

The teaching of surgery must be well supervised. Training should evolve through assisting, performing operative procedures assisted by a competent teacher, with progression to more independence as a senior resident. A man cannot learn surgery unless he does it.

Rounds and Conferences

Formal rounds should be conducted by the chief-of-service at least once a week, at which all members of the visiting staff and house staff are present. This may well be an amphitheater exercise. Cases should be presented by the house staff, and discussed by the house staff and the visiting staff. The residents must be able not only to present cases well, but also to give their ideas and to discuss the problem.

"Resident rounds", including the visiting staff and residents, should be made daily with all residents in attendance. The senior visiting men on service should be present for about one-half of the time devoted to these rounds. They should see the patients, discuss all problems, and consider new admissions.

Chief-of-Service-Resident Meeting: The chief-of-service should have a weekly meeting with the resident staff, both for discussion of administrative problems and to consider any question brought up by the residents, whether about a patient or not.

Regular Seminars: These should be diverse in character. They should include a presentation of papers prepared by members of the house staff. Ideally, each resident should have a research project for investigation and report. Journal reports may occupy some of the exercises, as well as talks by various members of the orthopaedic visiting staff or by men in various fields. X-ray conferences may occupy certain of the periods. The chief resident may be made responsible for arranging the exercises.

Orthopaedic Pathological Conferences and So-Called Basic-Science Activities: Pathological conferences should not be restricted in their material and should, as indicated, include such aspects as pathological physiology and biochemistry. It is our opinion that teaching in basic science during the children's training is best integrated with the clinical problems as they arise. The orthopaedic surgeon should be capable of participating in such instruction, with the consultants in the appropriate fields. A special orthopaedic laboratory, staffed with a director and research fellows, is very desirable, in that almost automatically there is a free interchange between the laboratory and clinical groups.

Combined Conference: A regular weekly exercise, participated in by all of the services concerned with children, is valuable. Each service presents a case for general discussion.

All trainees should be encouraged to attend the *general pathological conference* of the hospital.

Follow-up Clinics: Particularly desirable exercises are follow-up clinics, which are attended by all visiting men and residents. For these, various groups of patients are recalled for end-result observations, thus allowing the trainees to observe the results obtained from various types of procedures.

These exercises and comments have been listed to convey the types of activities which may go into a well-rounded training program in children's orthopaedic care, but again it should be emphasized that the program in its detail must be adjusted to its environment. The essentials still remain: adequate clinical material and stimulating teachers who spend time in teaching.

THE IDEAL CURRICULUM FOR BASIC-SCIENCE INSTRUCTION IN ORTHOPAEDIC SURGERY

By Guy A. Caldwell, M.D., New Orleans, Louisiana

Tulane University

In the course of graduate training for orthopaedic surgery, review of those portions of the basic sciences which are related to orthopaedic surgery is of fundamental importance. A thorough knowledge of the anatomy, pathology, and physiology of the musculoskeletal system is essential for a comprehensive *diagnosis* of the lesions encountered, and an equal understanding of bacteriology and biochemistry is required for efficient *treatment* of the patient and his impaired function.

Ideally, this basic-science knowledge should be acquired with each new orthopaedic condition that is encountered. It is a generally accepted principle of medical teaching that, as the student learns to recognize the clinical picture of a lesion in a given patient, he will retain this knowledge best if he immediately reviews the entire background of the problem presented. Such a review includes detailed examination of the anatomy of the parts involved, the pathological and histological alterations commonly observed, and the physiological changes encountered. If infection is present, or if the metabolism is altered, the student should consult the medical literature and study the laboratory techniques in bacteriology and biochemistry, in order to direct measures of treatment intelligently.

In the ideal curriculum, therefore, anatomical and pathological specimens should always be available for dissection, and free access should be had to consultants in physiology, bacteriology, and biochemistry, so that the student may discuss with them the problem in hand. This would enable the student to see the complete picture of the lesion, and thus to understand more intelligently the progress in treatment. The impression gained would then be indelible, and each similar problem encountered, with its minor variations, would be readily associated with the first one and equally well retained.

Such an ideal plan requires:

1. A limited, but varied, number of patients with orthopaedic problems;

2. Availability of anatomical and pathological material, adequate library facilities, and competent instructors or consultants in physiology, bacteriology, and biochemistry;

3. Sufficient time free from routine hospital duties to enable the student to do the necessary dissections and other studies.

However ideal such a plan of instruction may be, it obviously is impractical in view of the obligations of a resident to the hospital and in the care of patients assigned to the orthopaedic service. It is likewise impossible for graduate schools to provide instructors who can be available at all times to assist the student with problems in physiology and biochemistry. Nevertheless, close integration of a broader knowledge of the basic sciences with the clinical care of the patients should be the working principle.

Hospitals with orthopaedic services approved for three years of training, which are connected with medical schools, can most nearly approach this ideal plan of integrating the basic-science instruction with the clinical care of patients. The medical school should have at least the potentialities for anatomical and pathological specimens for dissection; there probably are adequate library facilities; and usually instructors in physiology, bacteriology, and biochemistry, who can be prevailed upon to assist in the solution of orthopaedic problems. However, the mere existence of such facilities and consultants will not guarantee their accessibility to the student. There must be an *organized plan* for the student to follow, an *interest and stimulus* to prompt him to seek the knowledge, and *sufficient time* for him to acquire this fundamental background.

The general plan for the trainee to follow should be formulated by the orthopaedic staff in conferences with teachers of the basic sciences. The interest and stimulus must be furnished by the staff, who, on ward rounds, at conferences, and in the operating rooms, take every opportunity to review the fundamental background of each case discussed. The time to be allowed residents and fellows must be arranged by agreement with hospital authorities, and must not be confined to evenings off duty and holidays.

It is important that all biopsies and specimens removed at operation be reported in detail at staff conferences; it is helpful for the surgeon to identify the anatomical structures encountered in making an operative approach, and to demonstrate to his assistants the gross pathological changes revealed through this exposure. Review of roentgenographic and laboratory findings and discussion of the difficult cases in conferences supplement the basic knowledge of the graduate students. However, if these are the only opportunities in the basic-science phases of orthopaedic entities, the students will be woefully lacking in many essentials. At most, such instruction gives them an incomplete picture of a few common conditions. Therefore, a plan should be adopted which will cover *all* the conditions met in orthopaedic practice. The graduate student will need the help of anatomical dissections, pathological demonstrations, and seminars in bacteriology, biochemistry, and physiology to acquire the necessary background for many problems which are encountered infrequently even on a large orthopaedic service.

Acceptable programs for providing basic-science instruction have been developed by many of the institutions; and, although they vary considerably as to distribution of time and arrangements for giving

instruction, all of them embody the foregoing fundamental requirements. They have a clearly defined program which seeks to cover the entire field; they have laboratory facilities and specimens available for dissection; and they provide instructors, either from the orthopaedic staff or basic-science teachers, or both, to conduct seminars and conferences; finally, they schedule a definite time in which the trainee may do this work. In some institutions, this phase of instruction is confined to one day a week throughout the three-year period of training. In other cases, the greater part of the first-year resident's time is devoted to the basic-science program. In still other instances, an intensive program is arranged to cover a period of six months, during which time the resident has no regular hospital duties.

Poor and unacceptable basic-science training still prevails in far too many hospitals. These hospitals generally fall into two groups. In the first group the program provides time (approximating six months) during which the trainee is released from other duties. A schedule is outlined whereby the trainee attends clinicopathological and radiological conferences, spends certain hours in laboratories of anatomy and pathology, and attends lectures in physiology and biochemistry. However, investigation often reveals that the conferences contain little relating to orthopaedic surgery; the anatomy and pathology are but a general review of material presented to undergraduate students by the preclinical faculty; and the lectures in physiology and biochemistry are routine, general ones given at the undergraduate level. No selection of those parts of the basic sciences relating to orthopaedic surgery has been made by the orthopaedic staff, and the staff does not participate in the instruction. Much that is given the trainee is far afield or completely irrelevant, because the orthopaedic staff has dodged its responsibility.

The second group of poor programs in the basic sciences consists of those supposedly integrated with the clinical work, but actually containing little more than a few crumbs of knowledge dropped by the surgeon in the course of routine ward rounds, while operating, or during staff conferences. The resident is advised now and then to "read up" on this or that, or to "run over to the dissecting room" and review this or that surgical exposure. As the time for Board examinations approaches, the staff man urges the trainee to "get someone in the Department of Pathology to show you some bone-tumor slides". No organized, comprehensive plan has been evolved by the staff; sufficient time has not been set aside; and, by precept and example, the orthopaedic surgeons indicate that the fundamental background of basic-science knowledge is not particularly essential. Their attitude is expressed in the remark sometimes heard: "It is unnecessary to spend so much time on basic-science studies; that knowledge will come to you as you go along with your clinical work." Such an attitude on the part of the senior surgeons fails to impart the necessary interest and stimulus to the resident to make him seek the fundamental knowledge he sorely needs.

The ideal program of basic-science instruction will not be realized until staff members themselves appreciate its value and importance enough to assist in formulating an organized plan of instruction for the residents, to help with the demonstrations and seminars, and to take every opportunity to discuss in the clinical conferences the fundamental background of each new condition encountered. Usually, assistance is needed from full-time instructors in the basic sciences, but the subjects covered by the instructors should be carefully chosen and their application to orthopaedic surgery should be explained by an orthopaedic surgeon.

As a means toward better teaching of the basic sciences, medical centers should develop orthopaedic surgeons with special interests and ability in one or another of the basic sciences. When we have several men in each center qualified as orthopaedic surgeons or interested in orthopaedic surgery—one who knows and teaches anatomy, as does Inman of the University of California; another who has learned pathology of bones and joints, as did Bennett of the University of Illinois; and another who is thoroughly familiar with bacteriology and wound infections, as is Meleney at Presbyterian Hospital—the basic sciences will be taught ideally. To this end, future staff members who are now residents or young assistants should begin special investigations in one or another of the basic-science fields. There should be funds to provide facilities and to subsidize their work. Thus, in a few years, each of these orthopaedic surgeons will have a broad and thorough knowledge of one of the basic subjects. He will contribute greatly to staff interest and can give proper instruction in that branch to the residents.

In conclusion, the ideal program for basic-science training should include:

1. A senior staff which appreciates the importance of this phase of training;

2. An organized, comprehensive program prepared by the orthopaedic staff, with assistance from basic-science teachers;

3. A working schedule for residents, which will provide adequate free time for personal study and preparation, and attendance at the scheduled conferences, demonstrations, and seminars;

4. A staff which will develop all the fundamental background of each new clinical entity as it is encountered on ward rounds and in the operating room, and will thus arouse the interest of the residents in thorough basic-science training;

5. Hospital and medical-school administrators who will secure funds to provide part-time salaries and laboratory facilities for young staff men, so that they will become interested in anatomy, pathology, physiology, and biochemistry.

THE IDEAL CURRICULUM OF RESIDENT TRAINING IN A UNIVERSITY CLINIC

By Carl E. Badgley, M.D., Ann Arbor, Michigan

University of Michigan

I agree with all that has been said. Now we come to the problem of the curriculum in a University Clinic. It seems to me that the problem is simply that in a University Clinic we are, in addition, teaching. There is an opportunity, which Dr. Caldwell has just suggested, of utilizing our University Centers for the purpose of acting as a mother center; and, through these, of developing an exchange service so that we may send our men to other institutions for a period of time for the purpose of having them acquire knowledge in a particular phase of our work. We have had such an arrangement for several years with Dr. Abbott at California and, more recently, with Dr. King at Stanford; we have also an exchange service with other hospitals. In addition, it is possible to utilize the University Centers for the teaching of the basic sciences to residents from outlying areas.

I agree with Dr. Green that one of the greatest things in the training of orthopaedic residents is the relationship with the men on other services. We need the broad knowledge that the men of the other services can impart to our men. We are very much pleased that such has been the case in the University Hospital in Ann Arbor, where all the surgical departments are closely interrelated. We do not regard ourselves as specialists particularly and, regardless of the surgeon, each group requires the same amount of training; the men are all on an equal level and they have many things which they can talk over. There are so many interdigitations in the various types of work in orthopaedic surgery which require knowledge of neurosurgery, thoracic surgery, vascular surgery, and various other fields, that such a plan of training, I believe, is absolutely essential.

It is important to have close cooperation with the department of medicine. Various problems arising in an orthopaedic department, such as thrombophlebitis, the fatigue syndrome, arthritis, gout, et cetera, need medical consultation.

Concerning pathology, I must pay tribute to the Orthopaedic Board. I think the Board has done a remarkable job in the stimulus it has given our residents to learn pathology. There is no doubt that, since the Board initiated this requirement, our men have been much more interested in pathology. Our departments of pathology and of anatomy are now appreciative of the need that our men have for this training, and we are developing a relationship we never had before. We have didactic teaching in pathology, which I think is good. However, the didactic teaching should not be on the level of one older pathologist to another, but should be on the level of the younger pathologist who is acquiring the knowledge which the older pathologist possesses. Lectures are given twice a week by just such a pathologist, and it has been valuable to all of us. We also have the daily examination of autopsy material.

Our relationship with the Department of Pediatrics has been close and is most satisfactory. Daily conferences in roentgenology are extremely stimulating. These related activities are all important in the development of our specialty and in the training of our men.

In our department, embryology is now playing an important role. We have had a project on the development of fascia, with work which has progressed so that it is of basic value. It has been done on foetal specimens at the University Hospital in our Surgical Department.

Concerning training in anatomy, merely the dissecting of the human body has never seemed to me to be the answer. One must do far more than dissect a cadaver. We allow three full months in the Department of Anatomy, in which time we anticipate that the resident will work on a research problem. The residents are utilized for the purpose of teaching. There is nothing more stimulating to the individual than the fact that he has to teach and at the same time has to know what he is teaching. If he can have this opportunity, it is far better than simply dissecting. In addition, our men teach surgical anatomy, which is also of great value to them. This is taught in the third year.

The teaching responsibilities in the University Clinic, of course, are minimal when these men are in training, but we utilize these residents to a considerable extent in the teaching of nurses; in various other departments, such as social service; in rehabilitation; and also in our out-patient clinics for the teaching of juniors and the teaching of the sophomores in fractures. I think the most important thing in the training of men is to give them a sense of responsibility. It is the sense of responsibility that stimulates residents to do their best work.

The residents also have the stimulus of learning to speak while standing on their feet, which is a very important part of training. The residents present their cases, completely worked up with a full résumé, at weekly conferences from nine to twelve on Saturday mornings. This is entirely their responsibility. Similarly, we have a fracture conference at which they present their cases. Having the individual responsibility of presenting a patient at conference makes it necessary for the resident to get the most out of the case.

THE IDEAL CURRICULUM OF RESIDENT TRAINING IN A PRIVATE CLINIC

By J. S. Speed, M.D., Memphis, Tennessee

The Campbell Clinic

The fundamental purpose of an orthopaedic residency is to train the young surgeon for the private practice of orthopaedic surgery. The ideal training program is found in neither the strictly charity hospital nor the strictly private hospital and clinic, but is found where experience is obtained in both types of institutions. For the resident in the private clinic and hospital, it is desirable, if possible, to add experience on a charity orthopaedic service, as well as in the allied specialties of plastic and neurological surgery. It is, of course, preferable that the charity services be directed by the same staff which controls the private clinic, so that the direction and character of the work will be of a uniform quality. However, if the charity service is directed by another staff, there will be a diversification of viewpoint, which is also of value.

By securing training in the private clinic, the resident can learn much of future value as regards the business side of medical practice, the practical aspects of handling patients, and the fundamental principles of planning treatment, which will conserve the patient's finances and yet keep his welfare uppermost. The type of patient seen in a private clinic and the diagnostic problems presented frequently differ in some respects from those seen on a charity service; consequently, the training gained in a private clinic will carry directly over into private practice.

The staff responsible for resident training in a private clinic must, of necessity, see that the training is well rounded and includes adequate instruction in the basic sciences. Too frequently the energies of the resident are consumed in work which does not promote his education and training. The schedule of training in the small private clinic cannot always be broken down into distinct services in which each of the major phases of orthopaedic surgery is given its proper representation; it is necessary, therefore, that a definite effort be made to see that the training offered the resident be properly balanced and complete.

The resident may obtain the necessary training in the basic sciences by attending an organized course in a graduate school of medicine or by integration of the basic sciences throughout the three years of residency. In the latter case, physiology and biochemistry can best be taught in conjunction with the medical phases of orthopaedic surgery, including the preoperative and postoperative care of the patients. Lectures on the various phases of the basic sciences should be given either by the staff or by members of the medical-school faculty. Surgical pathology can best be taught by a correlation of the clinical, roentgenographic, and operative findings of the individual cases with the gross and microscopic study of the tissue removed at surgery. On the medical service at the beginning of the residency, an intensive review of surgical pathology in general and of orthopaedic pathology in particular should be carried out.

An especially valuable phase of the training offered by the private clinic is the opportunity for taking histories and making physical examinations. Here the resident will "work up" the patient, order and review the roentgenograms and laboratory studies, and formulate his own impressions as to the correct diagnosis and treatment. Whenever possible, he should be present at the time the staff man sees and examines the patient, reviews the roentgenograms and laboratory findings, analyzes all data brought out, and finally discusses the case with the patient. In this way, the resident has the advantage of learning the line of reasoning which the staff man uses in determining the proper treatment in the individual case, for treatment in many instances must be adapted to the individual and his circumstances. The resident should have the opportunity of assisting at operation on the patients he has worked up, seeing them postoperatively in the hospital, and later seeing them when they return for check-up examinations.

During the first year of training, the resident should work entirely under the direct supervision of the clinical staff, the staff being responsible for all decisions, all operations, and all after-care. Later, as his experience increases, it is desirable that the resident's responsibility be increased, to include if possible an adequate amount of individual operative work.

The danger of a single point of view, particularly as regards treatment, must not be overlooked. This can be obviated to a large extent by regular literature meetings, at which the current orthopaedic literature is reviewed, and presentations on assigned subjects are discussed. In a strictly orthopaedic clinic, attendance at general hospital staff meetings and clinical-pathological conferences should be encouraged.

In our own private Orthopaedic Clinic and Hospital, an effort has been made to combine the advantages of training in a private clinic with those of a charity service. Over the years, a training program has been evolved which encompasses all phases of orthopaedic surgery, as well as training in the basic sciences and certain aspects of neurological and plastic surgery. An outline of this training program is offered as an example of how a private clinic and hospital can be integrated into a resident-training program.

In addition to experience with the private adult and with children's orthopaedic and fracture cases, there are available the facilities of a forty-bed hospital for crippled children, the state crippled-children's services with their active surgical service, a sixty-five-bed hospital for crippled adults, a city-hospital service of forty beds (chiefly for acute trauma), a poliomyelitis service in the city isolation hospital, and a fifteen-bed in-patient cerebral-palsy unit. One day a week, the out-patient clinics of the crippled children's and

adults' hospitals are conducted under supervision. There is also an affiliation with a neurosurgical clinic and a plastic surgeon, to provide services in the orthopaedic aspects of these specialties. The residents are actually responsible for the conduct of the charity services and they perform a majority of the surgical procedures upon these patients, always under close supervision.

There is a weekly staff conference, usually lasting two hours, at which pertinent roentgenograms and pathological preparations are studied and reviewed in the light of the clinical features of the case. A weekly lecture series is conducted, forty weeks a year. These lectures, each two hours in length, are planned over a three-year period to include both clinical orthopaedic subjects and the basic sciences; the clinical lectures are given by the Clinic staff, while the basic-science lectures are given by preclinical teachers of the medical school.

At the present time, the training program is arranged as follows:

First Year

1. Pathology and medical service in the private Clinic and Hospital, three months. This includes a study of all material going through the Pathology Laboratory, and a systematic study of bone pathology, including tumors. While on this service, the resident assists with the preoperative and postoperative care of the Hospital patients, and works in both the Clinic and Hospital on arthritis and peripheral-vascular cases.
2. Assistant in operating room and work in the private Clinic, six months.
3. First assistant in the operating room and resident in orthopaedic surgery in the private Hospital, with responsibility for daily ward rounds, weekly progress notes, and dressings, three months.

Second Year

1. Assistant resident, crippled children's service, three months.
2. Assistant resident, crippled adults' service, three months.
3. Resident, crippled adults' service, three months.
4. Fellowship in neurosurgery, three months.

Third Year

1. Fellowship in plastic surgery, three months.
2. Resident, crippled children's service, three months.
3. Assistant resident, city hospital (charity) service, three months.
4. Resident, city hospital (charity) service, three months.

RESIDENT TRAINING IN A VETERANS ADMINISTRATION HOSPITAL *

By Dana M. Street, M.D., Memphis, Tennessee

Veterans Administration Medical Teaching Group, Kennedy Hospital

These remarks refer specifically to the present program at Kennedy Veterans Administration Hospital.

Kennedy Hospital was built for the Army during the War and was one of the largest General Hospitals. It was acquired by the Veterans Administration in 1946 and the excellent equipment was retained. It is at present operated as a 1,400-bed General Medical and Surgical Hospital.

The Surgical Service is comprised of sections in all of the major specialties, each of which is headed by a member of the respective specialty board. The same applies to the medical and other services in the Hospital, so that consultations are readily obtained. The large, full-time staff is also on hand for conferences and seminars on all phases of medicine. Paraplegia forms a separate section. With 250 beds, Kennedy is one of the four paraplegic centers in the country for veterans.

The Orthopaedic Section and training can perhaps best be described by following the resident through the program. The Orthopaedic Section contains 144 beds, and has been approved by the Board for two years' training in adult orthopaedic surgery, fractures, and basic science. Three months of neurosurgery have been added, making a total of twenty-seven months.

To examine this in more detail, the resident spends his first six months as Junior on a fifty-three-bed ward for clean orthopaedic surgery and fractures. Two such wards, or 106 beds, are devoted to these cases. The case material seen by the resident is exceedingly good. The anticipated burden of osteomyelitis and back cases has not materialized; of the 2,130 patients admitted during the past two years, 1,017 or 50 per cent. have had fractures, only 190 or 10 per cent. have had osteomyelitis, and 358 or 15 per cent. have been back cases of all sorts. Patients with major traumatic injuries are brought from all parts of Tennessee,

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Arkansas, and Mississippi. Of the fractures, 8 per cent. are non-unions and 10 per cent. are compound.

The three months spent on the Paraplegia Section offer the resident an unusual opportunity to gain insight not only into severe injuries of the spine, but also into problems peculiar to paraplegics. Paramount is the prevention and treatment of decubitus ulcers which, besides loss of protein, may also lead to osteomyelitis and infection of the adjacent joints. Other problems are urinary-tract infection, fractures, and myositis ossificans. Since most of the paraplegics require braces, the resident becomes familiar with the Brace Shop, employing twelve brace mechanics and averaging over 100 new braces per month. During this three months he is also assigned to the service of Physical Medicine, and becomes familiar with physical-therapy apparatus, such as the Hubbard tank and the bar-bells of DeLorme; as well as occupational-therapy techniques and rehabilitative procedures, such as ambulation of amputees, stair-climbing for paraplegics, their getting from wheelchair to bed, from wheelchair into bath tub, et cetera.

The three-month period spent on the Neurosurgery Section is optional, but is felt by most of the residents to be very valuable because of the close relationship of the two specialties. Here the resident sees spinal-cord tumors, treats head injuries, and studies the mechanisms of pain. Early disc cases are treated conservatively in the Orthopaedic Department. Simple disc operations are done by the neurosurgeons, and those requiring fusion are done by both services as a combined procedure.

Although much basic science can be taught on the ward, such as protein metabolism, fluid and electrolyte balance, and blood replacement, we feel that six months under the direction of the Pathology Department is of value. The work is in autopsies and surgical specimens, supplemented by dissection of extremities, lectures at a neighboring institution, and reading. We believe that the resident's work should not be limited to orthopaedic material, since there is much to be learned in the fundamental principles of inflammation, neoplasia, and trauma from cases of other services. We are of the opinion that pathology cannot well be combined with ward work, because insufficient time remains for study. Contrary to the impression of some, the Veterans Administration resident does not check in at eight and out at five o'clock, but works day and night as the need for his services exists. His reading time for clinical subjects alone is limited.

The resident then returns to the orthopaedic wards, spending three months as Senior on a ward containing a twenty-bed section for osteomyelitis and an eighteen-bed section for bone tuberculosis. These sections are well separated from each other and from the clean wards. The tuberculosis cases are drawn from all of the southeastern states and form a good teaching series.

During the final six months, the resident is Senior on one of the fifty-three-bed clean wards. Having assisted in a wide variety of operations as a Junior, he now has complete charge of the ward, does most of the surgery on his patients, and directs their preoperative and postoperative treatment. The Chief of the Section assists him with his first case of each type, after which, depending upon his aptitude, he is allowed to operate without direct supervision. He is thus given gradually increasing responsibility as he develops the capacity to handle it. The more extensive procedures are done by the Section Chief.

Besides the ward work described, all of the residents participate in an out-patient clinic, two afternoons per week. Hospital patients of other services are seen in consultation at this time. Grand rounds are conducted one morning a week, when every patient on the Section is seen. An x-ray conference and an orthopaedic conference are held each week.

Although appointments are on a yearly basis, the entire twenty-seven months described are available to all of the residents unless they prove incompetent. An additional six months is available to a selected 50 per cent. in which to round out their experience. In the past two years we have performed 948 open operations. Of these, 247 or about 25 per cent. have been done by myself, 25 per cent. by the Senior Resident, and 50 per cent. by the Senior Ward Officers. A man staying two years may then expect sixty or more major operations and, with the additional six months, 120, plus many minor procedures. Therefore, the service is neither a pyramid nor a straight service, but rather a semi-pyramid. It avoids the chief drawback of the pyramid type—namely, the casting out of men with little or no operative experience—while at the same time the Senior Resident receives a widely representative group of cases. Although the program is patterned after the Board requirements, we are fundamentally interested in training the residents to practise orthopaedic surgery, and not merely to meet their requirements.

In summary, the strong features of the service are its excellent reconstructive and traumatic material, experience with paraplegics, complete facilities for physical medicine and rehabilitation, and effective mechanism for follow-up study. The weak points are the paucity of material in the older age group and in childhood. The older group is increasing yearly, and the lack of children is partially compensated for by an affiliation with a children's hospital, which takes care of 50 per cent. of our residents.

In order to carry out successfully such a program of gradually increasing responsibility on the part of the resident, it is imperative that he be not oversupervised by a large, fully trained staff. A full-time appointment for the Supervisor is advantageous, permitting him to divide his time more equally between clinical work, research, and teaching. Clinical work is necessary to maintain diagnostic acumen, technical skill, and insight into the patient's problems. Research advances the frontier and constitutes a necessary proving ground for new procedures. Teaching provides one of the best incentives for keeping up with advances and, as Hippocrates said, is a moral obligation.

RESIDENT TRAINING IN AN ARMY HOSPITAL

By Colonel Milton S. Thompson, Medical Corps, United States Army

Brooke General Hospital, Fort Sam Houston, Texas

The precipitous demobilization at the end of the last War threatened to leave hospitals full of ailing patients and empty of trained doctors. The prewar specialists, like Major General Norman T. Kirk, held responsible administrative positions; the younger men had had no specialty training; the graduate professional-education program was needed. This program was started in 1947 and is designed to provide specialty training for Army doctors.

Orthopaedic training is provided in six of the Army's fourteen named General Hospitals. These six are Walter Reed General Hospital in Washington; Oliver General Hospital in Augusta, Georgia; Fitzsimmons General Hospital in Denver; Letterman General Hospital in San Francisco; Brooke General Hospital in San Antonio, Texas; and Valley Forge General Hospital in Phoenixville, Pennsylvania. The professional personnel of these Hospitals consists of the assigned staff, plus the attending staff of qualified civilian specialists. Their effort to maintain the highest standards has earned the approval of the civilian councils and boards concerned with maintaining these standards.

As of January 25, 1949, 143 Regular Army Medical-Corps Officers have been certified as diplomates of American Specialty Boards [1], four of whom were certified in orthopaedic surgery.

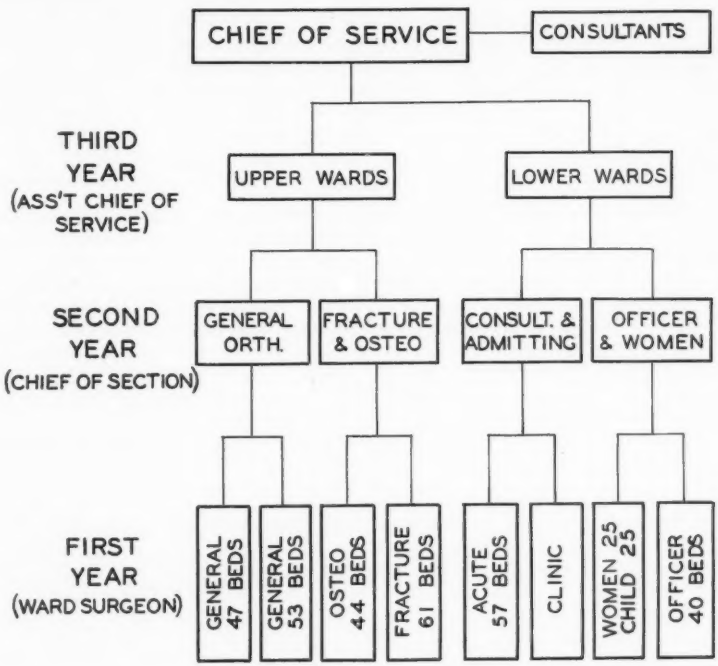

Fig. 1

At these residency-training hospitals, interns are selected from graduates of approved medical schools who are physically qualified for appointment in the Medical Reserve Corps. These men are given a one-year rotating internship, which includes one month on the Orthopaedic Service. Residents are selected from interns and from Regular Army Medical Officers who apply and who have the desired educational qualifications and aptitude. The residents are being assigned for three years of training, and rotate through positions of increasing responsibility.

There are some variations in the division of the services at the six hospitals, but typical is the organization at Brooke General Hospital (Fig. 1).

Formal teaching ward rounds are conducted. There are weekly Clinico-Pathological Clinics and Tumor Clinics, well-planned courses in anatomy with cadaver dissection, courses in pathology, and formal lectures on other basic-science subjects, given by qualified instructors. Monthly professional staff meetings, journal meetings, and problem clinics are attended, and the residents are welcome at x-ray, medical, surgical, and other conferences. The aim of this training is to encourage the residents to think in terms of long-range results.

The hospitals selected for residency training have not only fine physical plants with the most modern and complete equipment procurable, but abundant clinical material of all ages and kinds. Since they are General Hospitals serving wide areas, they are each at the "bottom of a funnel"; and, since their patients include not only soldiers, but also dependents, veterans, and retired personnel, the age and sex variation, as well as proportionate pathological training, is comparable with that of any civilian general hospital.

At Brooke General Hospital last year, 1,609 babies were born and 13,719 children were seen in the Out-Patient Department. Of these, about 600 visited the Orthopaedic Children's Clinic. The retired officers and soldiers and their dependents, as well as the veterans of the earlier wars, furnish material for training in geriatrics.

TABLE I

ORTHOPAEDIC SURGERY [2]

Hospital	In-patients Treated	Out-patient Visits	Operations Major	Operations Minor	No. of Residents Authorized	No. of Residents Present	Beds Allotted
Brooke	2,796	3,619	835	116	14	6	347
Fitzsimmons	1,136	2,931	702	139	8	5	264
Letterman	2,006	2,232	769	136	15	8	450
Oliver	1,815	1,052	549	497	14	4	561
Walter Reed	912	4,168	775	374	14	3	300
Valley Forge	1,083	707	753	152	11	0	370

We are enthusiastic about the graduate-education program, and hope that it will accomplish the purpose for which it was designed. In the field of orthopaedic training, we feel that it is definitely justifying its existence. Regular Army doctors have acquired skills and experience and have gone to staff hospitals in this country and abroad. In the two years which have elapsed since the inception of the program, Army residents in orthopaedic surgery have benefited from the experience of participation in a program which last year offered 9,748 patients and 5,797 operations in the six General Hospitals giving orthopaedic-residency training.

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RESIDENT TRAINING IN A NAVY HOSPITAL

BY JOSEPH S. BARR, M.D., BOSTON, MASSACHUSETTS

Reserve Consultant in Orthopaedic Surgery, Bureau of Medicine and Surgery, Navy Department

The Navy has conducted a graduate medical-training program for its regular medical officers since 1920. At the close of World War II, plans were made for expanding this training program, utilizing the facilities of Naval hospitals for residency training. At the pr sent time, United States Naval hospitals at San Diego, Long Beach, and Oakland, California; Bethesda, Maryland; Philadelphia, Pennsylvania; St. Albans, New York; and Chelsea, Massachusetts, are approved for residency training in orthopaedic surgery. The approval is for adult orthopaedic surgery, fractures, and basic sciences. No Naval hospitals are approved for training in children's orthopaedic surgery. At the present time, there are a total of twenty-nine Naval medical officers in resident training in orthopaedic surgery,—fourteen in Naval hospitals, and fifteen in civilian training centers. There are seven men at the first-year level of training, thirteen at the second-year level of training, and nine at the third-year level of training. Although only one Naval medical officer is now certified by the American Board of Orthopaedic Surgeons, several others have completed the require-

ments for Part II of the examination, and the Bureau of Medicine and Surgery expects to continue assigning medical officers to the training program in sufficient numbers so that, within a reasonable length of time, there will be a well-trained orthopaedic surgeon certified by the Board in each of the larger Naval hospitals.

The training program at the individual hospitals is similar to that at any of our better civilian institutions. The medical officers who are in the training program have volunteered for it. They have been carefully selected on the basis of ability; they have had adequate preliminary surgical training. In most of the Naval hospitals, civilian consultants bear a major part of the responsibility for the training program. Each resident is expected to spend at least a year in a civilian institution in children's orthopaedic surgery.

I believe that the Naval program is well organized to meet the needs of the Navy, and that it compares favorably with the training obtained in many, if not most, civilian institutions.

SPECIAL TRAINING THE RESIDENT SHOULD HAVE IN CEREBRAL PALSY

By Robert A. Knight, M.D., Memphis, Tennessee

The Campbell Clinic

Within recent years, a better understanding of the problems of the cerebral-palsy patient and his treatment has been encouraged, largely through the efforts of Dr. W. M. Phelps of Baltimore. In the past, there has been little to offer the patient with cerebral palsy other than surgery; and even this, in the light of our present knowledge, was in many instances ill-advised.

The treatment of the cerebral-palsy patient does not fall into the field of pure orthopaedic surgery alone, but overlaps into the fields of physical medicine, pediatrics, and neurology. Thus, anyone professing to treat intelligently the patient with cerebral palsy must master certain fundamental principles of these other specialties, in addition to those within his own realm, if he is to evaluate the case accurately and direct care along all the necessary lines.

By nature of his background training, the orthopaedic surgeon is best fitted to care for the cerebral-palsy patient, and it thus becomes our problem to plan the training of the resident so that he may, during his period of formal training, master the fundamentals of diagnosis and treatment. This may be accomplished in either of two ways:

The first method consists of attendance at an organized program in cerebral palsy. At the present time, the most highly developed teaching program is in operation at the Children's Rehabilitation Institute, under the direction and supervision of Dr. Phelps. As it is set up, it consists of three months' work, and includes experience in the various rehabilitative measures in addition to organized lectures, experience in the private office, and attendance at cerebral-palsy clinics. This special training is recommended for those men who have a special interest in the field and who contemplate being responsible for more than an average amount of work with crippled children, including the organization and conduct of a cerebral-palsy clinic and treatment center.

The second method, which will be most practical for the majority of the residents, is by the inclusion of adequate basic training in the principles of cerebral palsy during the year's work with crippled children. This can be gained by attendance at a weekly cerebral-palsy clinic, regular work in a cerebral-palsy unit associated with the children's hospital, and formal lectures covering the pathology, clinical types, and methods of treatment. During the course of a year, the resident should have gained a good basic knowledge of the subject, including the re-educative phases, as well as the proper place of both bracing and surgery.

Training of the cerebral-palsy patient can be carried out on either an in-patient or day-student basis; if personnel and funds permit, both types of training can be given. In planning a unit, multiples of fifteen patients are used, since a therapist can adequately carry a case-load of fifteen children with moderately severe handicaps; somewhat more than this number can be treated if their handicaps are less severe.

The staff needed for a fifteen-bed in-patient unit is as follows:

Medical director, part time (an orthopaedic surgeon with special training in cerebral palsy)
Physical therapist (with special cerebral-palsy training)
Occupational therapist (with special cerebral-palsy training)
Speech therapist (part time)
School teacher

Practically, the in-patient unit should function as an active training unit, admitting patients for periods of three months or longer. Certain patients can, after an initial period during which their training program is being set up in the unit, have the training carried out by the parents at home; others, because of their peculiar treatment needs, will require prolonged training at the treatment center. Before the patient is allowed to return home, his mother should come to the center for instruction so that she can intelligently carry out the child's therapy.

In large cities, the less severely handicapped children can be brought to the center daily. Their program is similar to that of the in-patients, but the cost of this day-unit type of training is less in that residence facilities are not required; the fact that the children are not taken from the home for a long period of time is advantageous from a psychological standpoint.

An in-patient unit of fifteen children, with a staff as described above, is in operation in conjunction with our own teaching program. The unit is closely integrated with the resident-training program, the residents on the children's service attending the weekly conference held by the director of the unit, as well as making daily visits to the unit. The experience and training which these residents gain would, of course, be greater and more diversified if the unit were larger, but it has been our experience that even a fifteen in-patient unit, with an active follow-up clinic, serves as a valuable training ground for the resident.

SPECIAL TRAINING FOR THE RESIDENT STAFF IN INFANTILE PARALYSIS

By Raymond E. Lenhard, M.D., Baltimore, Maryland

Johns Hopkins Hospital

The relationship of poliomyelitis to resident training is a vast topic. There are many facets to the problem, any one of which, if pursued to the end, would entail an extremely large amount of information.

A general outline might be briefly stated as follows:

1. Etiology
2. Epidemiology
3. Symptomatology
   A. Differential diagnosis
4. Pathology
   A. Changes in central nervous system
   B. Changes in muscles
5. Prognosis
6. Treatment
   A. Acute stage
   B. Convalescent stage
7. Bracing for treatment and for rehabilitation
8. Operative Phase
   A. Correction of deformities
   B. Improvement of function
9. Vocational Rehabilitation

One might suppose that it would be unnecessary to dwell too much with a resident staff on the problems of etiology, epidemiology, symptomatology, and pathology. They should know from their textbooks and medical training the basic facts, or as much as is known, of the disease. The diagnosis for a resident staff should be a simple problem.

They might be impressed with the prognosis and with the statement that many of the cases are unrecognized, but that, in those which have definitely been diagnosed, the recovery rate is rather high. In 60 per cent. of recognized cases, recovery is complete; another 20 per cent. of patients recover with a minimum of residual weakness or disability. About 2 per cent. have marked residuum, to the point where wheelchairs are required. It is in the other 18 per cent. that most of the problems arise in regard to prolonged treatment.

The residents, unless they are associated with a hospital for contagious diseases or one having contagious wards, will probably have very little opportunity to see the earliest stage of the disease, and may not have contact with patients for several weeks after the onset of the disease. However, they should be taught the use of a respirator and the need for tracheotomy.

They should become well acquainted with treatment at the convalescent stage, with the measures of physical therapy that are used, with the judicious use of heat, massage, and exercise, and with careful handling of the muscles and extremities involved. Some knowledge of how to record the progress of patients and of the muscle testing required for such records might be a part of the program.

Prophylactic measures during the recovery phase are essential, in an effort to prevent deformities or to diminish the amount of deformity of joints. The residents should know the fundamentals of the bracing and splinting of extremities in the prevention of deformities, and the problems connected with such bracing when the patients are permitted to be ambulatory.

When deformities exist, the teaching should include the mode of production of deformities as well as methods to correct them by muscle transplantation, tenodesis, and arthrodesis. Such broad statements need more specific description, but the after-care of poliomyelitis is essentially a problem of individual patients, and the best teaching is given at the bedside. Since the disease leaves characteristically a spotty weakness, the

deformities may be multiple, involve any joint, and be associated with varying degrees of muscle weakness.

The resident staff should also be acquainted with the fact that the poliomyelitis patient needs not only physical rehabilitation, but mental adjustment as well; and that, throughout the whole course of therapy, one should bear in mind the problems which may arise in regard to vocational rehabilitation.

SPECIAL TRAINING THE RESIDENT SHOULD HAVE IN THE FITTING AND MAKING OF BRACES AND PROSTHESES

By Atha Thomas, M.D., Denver, Colorado

University of Colorado School of Medicine

In reviewing orthopaedic literature through the years, one gains the impression that, as knowledge and interest in open surgical procedures increase and new surgical techniques develop, there has been a proportionate diminution in interest in the problem of orthopaedic braces and appliances. In spite of recent advances in the development of graduate orthopaedic teaching, sufficient effort or interest has not been shown in any organized or comprehensive instruction in the prescribing and fitting of braces, artificial limbs, and other orthopaedic appliances. This lack of instruction is evidenced by the confused and limited knowledge of the subject on the part of many of the younger orthopaedic surgeons. This deficiency became especially apparent when the military services established their own brace and limb shops during World War II.

Except in some of the larger institutions which have their own brace shops, little opportunity or time is available for the orthopaedic resident to receive instruction in orthopaedic appliances; and, even when a shop is available, little effort is made to organize formal instruction on the subject. This is especially true as regards artificial limbs. There are few modern texts on the subject, and the literature is meager and not readily available.

Too often braces are prescribed with little knowledge of the fundamental design and construction of the brace and with very vague ideas as to its purpose and function, this problem being left largely to the judgment and decision of the appliance-maker. In addition there rarely is adequate supervision of the fitting of the appliance and instruction in its use, in order to make sure that it properly fulfills the purpose for which it was designed. These matters all should be the responsibility of the prescribing physician, but too often they are left largely to the brace-maker or limb-maker.

The relationship of the physician and the appliance-maker has been aptly compared to that of the supervising architect and the building contractor. To prescribe and fit an orthopaedic appliance properly, the physician must not only possess a thorough understanding of the purposes of the brace, but also some knowledge of fundamental brace design and fabrication, materials available, and joint and lock mechanisms. Such knowledge is best gained by formal instruction, as well as by observation and experience in the shop.

Decisions as to the type of design or material used in braces are often made from habit or custom, rather than from a careful analysis of the individual patient's needs. Such considerations as age, general physical condition, extent of involvement, economic and social status, and length of time the brace will have to be worn are important factors in the selection of the design and material used. Judgment in these matters is attained through long experience or by adequate instruction.

In order to carry out such teaching properly, close cooperation between the physician and the appliance-maker is essential. Personal acquaintance with some of the leaders of the orthopaedic-appliance industry convinces me that they are eager to cooperate in such efforts, and I believe that it is to the mutual advantage of all concerned that this should be done. Well-organized instruction and demonstrations in fundamental engineering principles, brace design, simple metallurgy, shop practices in metal, wood, and leather work, principles of measurement, and fitting are all desirable in such a teaching program. I am sure that considerable teaching talent is available within the industry. The members of the orthopaedic-appliance industry are eager to improve their own standards and to organize and enlarge their training facilities; they believe that this can best be accomplished by cooperation with, and by the assistance and encouragement of, orthopaedic surgeons.

The instructional course in brace-making given by the Mellon Institute and University of Pittsburgh Medical School for both physicians and appliance-makers last fall was most worth while, and is a good example of such cooperative effort. I understand that the course is to be repeated this fall in a slightly different form.

The efforts of the Academy in cooperation with the Army, Veterans Administration, and the orthopaedic-appliance industry in preparing a comprehensive Atlas on Braces and Artificial Limbs is also most commendable; the Atlas, when published, will furnish valuable material for the teaching of residents. In addition, however, it is highly desirable that a formal teaching program be devoted to orthopaedic appliances, a curriculum being set up to include lectures and demonstrations and possibly even some shop experience. It is only by such a program that this subject, so essential in orthopaedic practice, can be taught adequately.

RESEARCH, PUBLICATIONS, PHYSICAL MEDICINE, AND OTHER SPECIAL SUBJECTS IN A RESIDENT-TRAINING PROGRAM

By Fremont A. Chandler, M.D., Chicago, Illinois

University of Illinois

Research and Publications

The rush and glamor of an ever-widening clinical experience is attractive to every resident, as it is to most practising orthopaedic surgeons. Research and the publication of scientific papers consequently have been relegated to a minor role in many courses for training of residents. Only late in their course do most of these surgeons begin to appreciate the need and satisfaction of investigative effort. Many enter active practice, hoping to devote sufficient time to serious study, little realizing that facilities and guidance are no longer at their disposal. Their economic advancement stifles them further and they join the ranks of imitators, well disposed to allow others to advance the science of their specialty.

The desire for true knowledge must come from an inherent curiosity, leavened with some degree of skepticism for available data. Fire of this nature is instilled into the resident only with great difficulty by hard-working, mentally agile preceptors. The usual course of collegiate and medical education fails in high degree in the accomplishment of this phase.

How may we function best in correcting this situation which confronts us?

1. Clinical research depends largely upon the study of patient records, past and present. The assignment of a statistical review of some specific orthopaedic entity to the new resident will give him an opportunity of appreciating the shortcomings of his predecessors and will emphasize the need of intelligent and accurate recordings of data.

2. Although most residents feel capable of mastering big problems, it is usually desirable to initiate their investigative efforts under the direct guidance of some productive worker.

3. The presentation of case reports, supplemented by reviews of the literature, affords an opportunity for the resident to become acquainted with library technique and with the various publications especially related to the subject.

4. The preparation of these case reports and the active participation of the resident in clinical conferences adds impetus to his interest in this phase of training.

5. The requirement of a thesis brings out latent ability which may otherwise remain hidden.

Special training in the following fields is of value:

Physical Medicine

It is difficult to summarize specific subjects in this field, for the practice of physical medicine employs techniques, many of which border on psychological methods of therapy. These are proper if employed properly.

So little is known regarding the actual physiological response of tissue to the various stimuli that training in this field must be clinical in nature. This would indicate that the resident might well become a temporary member of the Department of Physical Medicine, actually participating in the administration of the prescribed procedures. By doing so, he will appreciate the merits of technique and will be in a position to prescribe therapy more specifically. Familiarity with the use of the thermocouple, the electromyograph, and the numerous means of recording circulatory changes will enable the resident to recognize the opportunities of clinical application as he comes into contact with patients.

Instruction by members of the Department of Physical Medicine is desirable. This should come early in the period of orthopaedic training.

Roentgenology

The extensive use of the roentgen ray in orthopaedic surgery makes this subject of major importance. To properly appreciate the intricacies of roentgenology as it serves the purpose of orthopaedic diagnosis, a knowledge of photographic technique and of the actual manipulation of roentgenographic equipment is most desirable. Although the final film is the immediate need of the orthopaedic surgeon, familiarity with the complex techniques required in its production will be beneficial. This can come only through actual use of the equipment. Nothing is of more value than serving as a technician for a short period.

Interpretation of roentgenograms is, of course, the major problem. Training in this phase is best accomplished by close contact with the roentgenologist and clinician, through the medium of frequent conferences.

Neurology and Rheumatology

Needless to say, experience and knowledge in these fields is of vital importance, but it may best be acquired through day-to-day contact rather than by isolated courses of instruction. Certainly neurological entities must be recognized by the orthopaedic surgeon, for many are reflected through dysfunctions of muscles and joints. The principles of neurosurgery should not be overlooked.

THE GRADUATE SCHOOL OF MEDICINE

Course in Orthopaedic Surgery and Its Curriculum

By Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania

University of Pennsylvania Graduate School of Medicine

The Graduate School of Medicine at the University of Pennsylvania was established in 1916 by merger of the Medico-Chirurgical College and Hospital, the Diagnostic and Howard Hospitals, and the North American Sanatorium, and by various philanthropic gifts. Its purpose was to provide "basic" graduate study in the well-recognized clinical specialties. This graduate study was "intended to lay a foundation and to prepare for appropriate clinical and thesis studies to succeed the basic studies".

The clinical and thesis studies may lead to a graduate medical candidacy, providing the Faculty are convinced that the candidate is qualified to practise the clinical speciality concerned. "The Faculty becomes convinced . . . in either of two manners: (a) By the fact that the candidate has become a certificant ('diplomate') of the related American Board for the certification of such clinical specialists; or (b) that the candidate has fully completed all the detailed precepteeship or fellowship requirements, including certification as to special clinical qualifications by the officially designated preceptor(s) or fellowship director(s).

"Precepteeships may proceed in several manners: hospital residentships; or resident or visiting hospital or clinical fellowships or assistantships; or assistantships in private special clinical practices of preceptors in approvable part-time combination with one or more of the foregoing hospital associations." They have as common features: "(a) Approved study facilities; (b) an approved preceptor who cooperates with the preceptee and the University; (c) a duration of two or more years, if the candidate be engaged solely in his precepteeship studies; (d) a duration of three or more years if the candidate engages in clinical (or other occupational) pursuits in addition to his precepteeship studies; (e) an academic credit of two thousand hours or more in two years or more of study, and no credit being given for private practice of the candidate; (f) preparation of an approvable thesis, involving an acceptable degree of original investigation pertaining to the clinical field concerned in the candidacy; (g) the preparation of the thesis must be authorized and active while the practical credits are being accumulated, but it is not necessary that the thesis requirement shall have become fulfilled completely at the time that the practical requirements become fulfilled,—an extension of time for the fulfillment of the thesis requirement being allowable at the joint discretion of the preceptor, dean, and faculty; (h) periodic preceptorial and faculty approval of the practical and thesis studies as they proceed; (i) final general preceptorial and faculty approval of the special practical status which the candidate has attained, and approval of his completed, unpublished, thesis."

For a Master's degree in (medical) science, two calendar years of clinical and thesis studies are required. For a doctorate in (medical) science, one to three years are devoted to research in the field of the specialty concerned.

"Separate basic studies are provided for each of the (sixteen) clinical specialties currently accorded major recognition by the school's curricula: internal medicine, pediatrics, neurology-psychiatry, dermatology-syphilology, radiology, surgery, gynecology-obstetrics, orthopaedics, urology, ophthalmology, otolaryngology, physical medicine, anaesthesiology, orthodontics, oral surgery-oral anaesthesia, oral medicine-periodontics and prosthetics."

The Department of Orthopaedic Surgery was established in 1920. The Chairman or Vice Dean was Dr. DeForest P. Willard, who retired from this chair in 1946. His observation and experience were responsible for the evolution of the course as presented today.

The school term extends from October to May. The enrollment is restricted to twelve. This number facilitates instruction in anatomical dissection and microscopic pathology, permits small sections for ward rounds, surgical theater, and out-patient clinic, and allows better evaluation of student potentialities by the instructors.

The schedule comprises thirty-two weeks. Each week has thirty-seven hours of assigned work, giving a total of 1,184 hours for the term. These assigned hours of work are broken down as follows: 586 hours are devoted to basic studies; 210 of the basic-study hours are occupied by lectures and clinical demonstrations in the correlated clinical-science course. This course is given by the separate departments of Physiological Chemistry, Pathology, Physiology-Pharmacology, Bacteriology and Immunology, and Physical Anthropology in the Graduate School of Medicine. These staffs combine to give an integrated course. The following is the present general arrangement of lectures:

1. Kidney (26 lectures)
2. Circulation (23 lectures)
3. Heart (15 lectures)
4. Blood (13 lectures)
5. Alimentary Tract (17 lectures)
6. Liver and Gall Bladder (11 lectures)
7. Metabolism and Nutrition (17 lectures)

8. Endocrines (20 lectures)
9. Nervous System (25 lectures)
10. Physical Medicine (6 lectures)
11. Lungs (22 lectures)
12. Microbiology (15 lectures)

In addition to this correlated clinical-science course, lectures in special physiology (14 hours) and biochemistry (12 hours) are given by the departments to the students in orthopaedic surgery. Separate courses are given the orthopaedic students in anatomical dissection and cadaver surgery (192 hours) and in gross and microscopic pathology of bones, joints, muscles, and tendons (160 hours).

Two hundred seventy-three hours are spent upon subjects related or responsible for orthopaedic complaints and methods of rehabilitation. Radiology occupies sixty-seven hours; neurology, ninety-six hours; neurosurgery, four hours; peripheral-vascular diseases, twenty hours; anaesthesia, sixteen hours; arthritis, twenty hours; physical medicine, ten hours; occupational therapy, six hours; plastic surgery, twenty hours; blood dyscrasias, six hours; dietary deficiencies, four hours; and bone metabolism, four hours.

Three hundred twenty-three hours are directly devoted to orthopaedic surgery. For much of this schedule, the student group of twelve is divided into three sections. The clinical observations are facilitated by the affiliated teaching of the following hospitals and institutions:

Philadelphia Children's Hospital: For children's surgery, out-patient clinic, and acute orthopaedic illnesses of children;
Philadelphia Shriners' Hospital: For children's surgery and ward rounds;
The Widener School for Crippled Children: For kinesiology, poliomyelitis, and cerebral palsy;
The Alfred I. duFont Institute of the Nemours Foundation: For clinics on deformities of children;
The Presbyterian Hospital: For plastic surgery;
Naval Hospital: For amputations;
Valley Forge General Hospital: For hand surgery;
Philadelphia General Hospital: For fractures;
Temple University Hospital: For ward rounds;
The University Hospital: For clinical conferences;
Graduate Hospital: For adult surgery and out-patient clinic.

Collateral reading in unassigned hours is stimulated by the assignment of an orthopaedic subject of general interest. Each week, before the student conference, one member of the group presents an up-to-date summary of his assigned subject with a pertinent bibliography. If the presentation is approved, it is mimeographed for distribution to other members of the class.

The limitations of the course are:

1. The students are at all stages of their required three years of orthopaedic training.
2. Little opportunity is afforded to begin or to continue a research problem.
3. But six-months' credit is given by the Board of Orthopaedic Surgery for a scholastic year.
4. There is no integration between the course and the additional years of resident training required by the Board of Orthopaedic Surgery.

Some progress has been made in the latter instance. Two general hospitals and one clinic have sent their residents to the Graduate School for the basic course in orthopaedics for the past three years. With such a plan projected with other hospitals and clinics, the students might, by such a reciprocal arrangement, be enabled to meet full requirements of The American Board of Orthopaedic Surgery while completing research investigation that would entitle them to a degree of Master of Medical Science from the Graduate School of Medicine.

NOTE: Quotations are taken from the Announcement for Session, 1949–1950, Graduate School of Medicine, published by the University of Pennsylvania.

WHAT CONSTITUTES A SATISFACTORY PRECEPTORSHIP TRAINING?

BY J. ALBERT KEY, M.D., ST. LOUIS, MISSOURI
Washington University

A preceptorship type of training is not an easy way to become an orthopaedic surgeon. The candidate who chooses this is usually one who, for economic reasons, does not find it possible to complete the formal orthopaedic program required by our Board. Such a candidate is apt to be a serious student who has more than the average allotment of ambition and energy. He should have an acceptable medical education, plus at

least one and preferably two years of training in general surgery. It is also desirable, but not essential, that he have a year's formal training in orthopaedic surgery.

Given this background, the candidate embarks upon a course which will eventually enable him to develop into an orthopaedic surgeon whose ability will compare favorably with that of his peers. I use the term "develop" advisedly, because I wish to emphasize the fact that in the preceptorship, or what I prefer to call the informal, type of orthopaedic training, the candidate is no longer an undergraduate student whose tasks will be allotted to him each day, but is one who has begun his life's work and is largely on his own. Much of what he does in the future will depend upon his own initiative, rather than upon an instructor. He is not going to be run through an orthopaedic mill and be delivered to the community as a finished product. It is for this reason that this type of training is suitable only for the candidate who has more than the average amount of determination. He should also realize that the period of training will be prolonged.

The amount of time which he should spend in informal training will vary with the ability of the candidate and with the opportunities for learning and experience which are afforded in his situation. In an average situation, he should spend approximately twice as long in informal training as he would in formal training. Under our present system, if he has had no formal orthopaedic training, he should plan on about six years of study and work before he is in a position to request examination with a view to certification by our American Board. On the other hand, if he has had one year of formal training, he should plan on four years of informal training. Since he will have been actively engaged in the practice of orthopaedic surgery during much of this time, it might be well for our Board to recognize this and to permit him to take his final examination at the end of his course of informal training, rather than after two additional years of practice.

The candidate should associate himself with an established orthopaedic surgeon of recognized ability. He will act as an assistant and receive a moderate salary, which will enable him to be self-supporting or partially so. In the beginning, he will not contribute a great deal to the partnership; but, as he gains in knowledge and ability, his contributions will be more important and his monetary compensation will be increased.

It is important that the senior member of the team—the preceptor, if you choose to call him that, although his status is far removed from that of a tutor—be genuinely interested in the development of his young associate. If this is true, the candidate will not be exploited, but will be given ample opportunities for mastering his specialty. He will be stimulated to study his textbooks and the current orthopaedic literature; and, from time to time, he will be advised to pursue comprehensive courses of reading on specific subjects in order that he may become familiar with the manner in which our present knowledge of orthopaedic surgery has evolved.

The candidate will not be exposed to formal courses or laboratory demonstrations in the basic medical sciences, in a futile effort to repeat his first two years of medical school, but he will be encouraged to refresh and perfect his knowledge of the anatomy of the spine and extremities and to keep abreast of those advances in physiology, biochemistry, bacteriology, pharmacology, and pathology which are of interest to modern orthopaedic surgeons. He will be stimulated to spend some time in the clinical laboratory of the hospital with which he is associated, and to study the microscopic preparations of the lesions which he encounters at the operating table.

In clinical orthopaedic surgery, the candidate will at first observe, and then take the histories of and examine patients. Then he and the senior member will go over these patients together and will discuss the diagnosis and treatment. He will become proficient in the application of the various conservative measures used in orthopaedic surgery and in the successful handling of patients. He will assist in operations, become skillful in the use of plaster-of-Paris and braces, and in the after-care of patients both in the hospital and after they leave the hospital.

As the young man's knowledge and ability increase, he will be given more responsibility in the care of patients and will be permitted to perform the simpler types of operations, reduce the less difficult fractures, and to continue the treatment of these patients until the end result has been reached. In doing this, he will have it impressed upon him that restoration of normal function is very often the object of his treatment. In his efforts to attain this, he will learn the usefulness and the limitations of physical therapy.

If a free clinic is available, he will be given an opportunity to work in this clinic and, when he is capable of performing such duties, he will be assigned to a ward service in the hospital. If there is a medical school located in his community, an effort should be made to have the younger man assist in the instruction of students. He should also be assigned some specific problem for investigation and study and, if he has a bent for either clinical or laboratory research, this should be encouraged and he should be allowed time to devote to the problem. He should be encouraged to attend and participate in medical meetings, and should be given the opportunity to do so.

Finally, as his judgment matures, he should be permitted to make decisions of increasing gravity and to assume responsibility for the solution of the more serious problems which are encountered in our specialty.

Under such a regimen, I believe that it is possible to develop a man who, while not a walking encyclopedia of medical science, is a very satisfactory orthopaedic surgeon. In fact, it has been done again and again. The reason it is not done more frequently is because both the candidate and the preceptor must be men of exceptional character.

RESULTS OF THE SURVEY ON THE REQUIREMENTS FOR BASIC-SCIENCE TRAINING

By Francis M. McKeever, M.D., Los Angeles, California
The American Board of Orthopaedic Surgery, Inc.

For several years The American Board of Orthopaedic Surgery has insisted that, during the three-year period of specialized training in orthopaedic surgery, time equivalent to six months be devoted to training in the basic sciences; the Board has so outlined its training requirements. This can be satisfied by integrating the basic-science training in the three-year period (which is considered preferable) or, in instances where instruction in basic sciences is not available, it has been possible to satisfy this requirement by a course of six months devoted to the study of the basic sciences.

In order to evaluate this requirement, a poll was made of 500 individuals who had taken one or both parts of the examination of The American Board of Orthopaedic Surgery during the years 1946 to 1948. The following questionnaire was sent to these 500 individuals:

"Dear Doctor:

The following questionnaire is sent to you in order that The American Board of Orthopaedic Surgery may evaluate its requirement of six months' resident training in the Basic Sciences. It is hoped that you will answer the following questions in the spirit in which they are requested, giving your opinion as to the value of this requirement to you and any constructive criticism which you may consider pertinent.

If you have not completed the examinations, your answers will have absolutely no bearing on your eligibility.

1. Have you completed Part I examination?.....
2. Have you completed Part II examination?.....
3. How did you meet the Basic Science requirement?
   (a) Special course at University?.....
   Where?.....
   (b) Integrated with clinical training?.....
   Where?.....
4. If you took a special course in Basic Science, at what time in your resident training period did you take it, the end of 1st year, 2nd year, etc?.....
5. What benefits did you derive from your Basic Science training? .....
6. Additional comments:

(Name).....
(Address)....."

Of the 330 individuals who had taken both Part I and Part II, 231 replied. The questionnaire was also sent to 170 who had taken only Part I; 133 of this group returned the questionnaire. A total of 364 questionnaires were returned.

The questionnaires of those who had taken Part I and Part II, and of those who had taken only Part I, were analyzed separately, as it was felt that the latter group might have a certain reticence in answering the questions. This, however, did not prove to be the case.

Twenty-five individuals, or 6.8 per cent. of those who replied, disapproved of the basic-science requirement. The percentage of those disapproving varied practically none in each group. The requirement was approved by 93.2 per cent.

Statistics—Part I Only Completed

1. *Total Number of Questionnaires Sent*		170	
2. *Total Replies Received*		133	
Integrated training	59		
Special courses	46		
Integrated and special courses	26		
None	2		
	133		
3. *Nature of Replies*			
Approved plan, with special comment	123		93.2%
Approved plan, without comment	1		
Disapproved	9		6.8%
4. *Subjects Especially Approved*			
Anatomy	74		
Pathology	69		
Physiology	27		

Biochemistry 11
Bacteriology 2

5. *Special Courses*

Location	*No. Attending*	*Location*	*No. Attending*
Columbia University	8	University of California	1
Northwestern University	6	Alabama University	1
Pennsylvania University	4	Illinois University	1
Iowa University	3	Ohio State University	1
Washington University	2	University of Colorado	1
Kansas University	2	University of Texas	1
University of Buffalo	2	University of Toronto	1
Wisconsin University	2	Marquette University	1
University of Minnesota	2	College of Medical Evangelists	1
Tulane University	1	Kennedy Veterans Administration Hospital	1
Oregon University	1		

6. *Approved Integrated Plan of Training*

Those who had had integrated course 21
Those who had had special courses 11
Those who had had both types of basic-science training 4
36

7. *Approved Separate Course*

Those who had had special courses 3
Those who had had both types of training 1

(The reason expressed in the questionnaires for such approval was the "relief from the care of patients".)

8. *Special Opinions*

One year of general medicine was advised by one man.
Two individuals felt that basic science should not start until after one year of clinical work.

STATISTICS—PART I AND PART II COMPLETED

1. *Total Number of Questionnaires Sent* 330
2. *Total Replies Received* 231

Integrated training 181
Special courses 38
No basic-sciences courses 12
231

3. *Nature of Replies*

Approved plan, with special comment . . . . . 208 } —93%
Approved plan, without comment . . . . . 7 }
Disapproved plan 16 7%

4. *Subjects Especially Approved*

Anatomy 95
Pathology 87
Physiology 33
Biochemistry 12
Bacteriology 5
Pharmacology 1

5. *Special Courses*

Location	*No. Attending*	*Location*	*No. Attending*
Iowa University	11	New York University	1
Northwestern University	7	Temple University	1
Columbia University	3	University of Chicago	1
Tulane University	3	Wisconsin University	1
Southwestern University	2	Marquette University	1
Pennsylvania University	1	Howard University	1
McGill University	1	College of Medical Evangelists	1
Baylor University	1	Germany	1

6. *Approved Integrated Plan of Training*

Those who had had integrated training 37
Those who had had separate courses 5
Those who had had some of both types 4
46

7. *Approved Separate Course*
   Those who had had separate course 2
   Those who had had integrated course 1
8. *Special Opinions*
   Ten expressed opinions that basic sciences should not be commenced until after one year or more of clinical training. It was felt that candidates would then be better oriented.
   Two believed general pathology was overemphasized.
   One believed training in neurology desirable.
   One believed training in general medicine desirable.

The following conclusions seem justified from this survey:

1. The basic-science requirement should be continued.

2. Clinical residencies should not be accredited for basic-science training unless they present evidence of *personnel*, *equipment*, and *time allocation* for the adequate teaching of anatomy and pathology, and show evidence of an affiliation for the proper instruction in physiology and biochemistry by qualified personnel.

3. Basic-science courses in a few teaching centers should be encouraged to continue, in order to supplement and round out the training of those individuals who do their clinical work in places inadequate for proper basic-science training. In this way, no clinical facilities will be wasted.

4. Basic-science courses which are given as a separate period of instruction should be so organized that the students are kept in some contact with clinical work during their instruction in the basic sciences. This might be accomplished by having the students in basic science attend rounds twice weekly or serve a part-time clerkship on orthopaedic services in hospitals during their period of basic-science training.

NOTE: Unfortunately the comments of those filling out the questionnaires cannot be included here, due to lack of space.

THE AMERICAN COLLEGE OF SURGEONS

TRAINING IN SURGERY AND THE SURGICAL SPECIALTIES

BY PHILIP D. WILSON, M.D., NEW YORK, N. Y.

Hospital for Special Surgery

The interest of the American College of Surgeons in graduate training in surgery and the surgical specialties is a natural outgrowth of one of the principal purposes for which it was founded,—namely, the elevation of the standards of surgical practice in the United States and Canada. Committees of the College began the study and discussion of different plans of surgical training as early as 1930. In 1936, the Board of Regents passed a resolution, requiring that applicants for fellowship in the College, who had received their qualifying medical degrees between the years of 1938 and 1944, should present evidence of having completed three years of hospital service following graduation, of which two years should have been spent in training in surgery or the surgical specialties.

There was a further elevation of the requirements for admission to fellowship in the College in 1945, when the Board of Regents adopted a resolution requiring four years of hospital service for applicants who had graduated from medical school after 1945, of which three years should have been spent in training in surgery or the surgical specialties in hospitals approved by the College and in such study of the basic medical sciences as might be considered necessary. In October 1948, the requirements for training in general surgery were raised to four years following internship.

When the College, in 1936, decided that it must approve the facilities of a hospital for training in surgery or the surgical specialties, it became necessary to add inspection of the educational activities of the hospital to the investigation previously carried on to ascertain whether the hospital should be approved as complying with the program of minimal standards.

In 1937, by action of the Board of Regents, a Committee on Graduate Training in Surgery was established, to which were appointed general surgeons and representatives of all of the surgical specialties. This Committee was given the task of investigating and evaluating the opportunities for training in surgery and the surgical specialties in all of the hospitals in the United States and Canada. As a member of that Committee since its beginning, I can testify that its members have taken their responsibilities seriously and have worked hard in reviewing and passing on the reports of training programs, submitted by the full-time field investigators. The College has been fortunate in securing, on a short-time basis, the services of several young surgeons who have themselves recently completed training in surgery, so that they are familiar with the requirements for good training programs. Their investigations have not been perfunctory inquiries into form, but have penetrated deeply into content as well.

In order to avoid the necessity of frequent meetings of the Committee, the Director of Educational Ac-

tivities of the College, Dr. George H. Miller, now causes to be sent to each of the members of the Committee full reports of the investigations of the training programs of hospitals that are applying for approval, as soon as they are received, and the members have the opportunity of passing on them without delay. Approval is by unanimous vote and, if there is difference of opinion, the further consideration of that program is postponed until the next meeting of the Committee.

To give an idea of the educational activities of the American College of Surgeons as represented by its latest report, published in the approval number of its *Bulletin* in December 1948, I may point out that of the 2,561 hospitals which have been approved by the College's Hospital Standardization Department as complying with its minimum standard requirements, there were 340 hospitals with 738 graduate-training programs which had been approved by the Graduate Training Committee. Approximately 3,900 doctors were serving residencies in surgery or the surgical specialties in these hospitals.

With respect to training in orthopaedic surgery, fifty-six programs in civil hospitals had received approval. In addition, a considerable number of Government-operated hospitals were conducting approved programs, including five by the United States Army, one by the United States Public Health Service, seven by the United States Navy, and twenty-six by the Veterans Administration.

There is one particular feature of the College program of evaluating graduate-training plans which needs to be emphasized, and which explains why the number of orthopaedic programs which have been approved by the College is smaller than that approved by the American Medical Association. The College insists that, for approval, a fully coordinated three-year training program should be carried out. The Committee on Graduate Training feels that programs of one or two years cannot lead to progressive increase of responsibility on the part of the resident, in keeping with the increase in his experience and knowledge, and also that they leave the resident in doubt as to obtaining the additional period of training that he may require. Furthermore, hospitals that offer training for periods of less than three years are generally not functioning in affiliation with a medical school or a medical center, or they would have been able to work out a coordinated three-year program in cooperation with other hospitals. Generally speaking, such hospitals do not have well-organized departments and the training facilities are not so good as they should be.

From this statement it can also be seen that many more hospitals have been approved for orthopaedic training than the fifty-six mentioned, because many of them have coordinated programs with other hospitals. It is the feeling of the Committee on Graduate Training that it is better to withhold approval of short training programs and to encourage these hospitals either to work out coordinated three-year programs or to devote their educational activities to general instead of to specialty training.

The reports on training programs in orthopaedic surgery which are sent in by the field investigators now include an analysis of the resident's experience, both with respect to clinical material and operations, in each of three major divisions—namely, pediatrics, surgery, and adult orthopaedics and fractures—as well as in the study of the basic medical sciences. In addition, the reports include such statistical material on special work with poliomyelitis, club-foot, cerebral palsy, and scoliosis as may be obtained. This type of comprehensive report gives a clear picture of the work being done and makes the task of evaluation fairly easy.

What is most needed now is up-to-date factual material with respect to each of the approved training programs in the various hospitals. This information should be available for the benefit of prospective residents, as well as for the American College of Surgeons, the American Medical Association, and the Specialty Boards. To obtain such material, annual follow-up inspections are required, to report on changes that are made in the various programs and how they are working out. Both the American Medical Association and the College of Surgeons are engaged in these investigative activities, with some duplication of each other's services. A pooling of their efforts is greatly to be desired, leading to more effectual and comprehensive annual check-ups on these training programs. Above all, agreement should be reached between these two great medical organizations with respect to the policy to be followed in approving and disapproving training programs, in order that the residents may not be confused, as they are at present, by differences in the lists of hospitals approved for training.

THE AMERICAN MEDICAL ASSOCIATION AND SPECIALTY TRAINING

By F. H. Arestad, M.D., Chicago, Illinois

Council on Medical Education and Hospitals, American Medical Association

First, I wish to extend greetings from the Council on Medical Education and Hospitals and to express my own personal appreciation for the privilege and opportunity of meeting with you again.

Since your last meeting in Quebec, the major survey of medical education sponsored jointly by the Council on Medical Education and Hospitals and the Association of American Medical Colleges has been organized and is well under way, under the full-time direction of Dr. John E. Deitrick, Associate Professor

of Medicine, Cornell University Medical College, and Director of Postgraduate Instruction of the Second (Cornell) Division, Bellevue Hospital, New York City. This comprehensive study, which will extend over a period of three years, will be conducted under the supervision and guidance of the Survey Committee on Medical Education, consisting of the following members:

Alan Valentine, Litt.D., Chairman, President of the University of Rochester
Dr. Arthur C. Bachmeyer, Associate Dean, University of Chicago School of Medicine
Dr. Herman G. Weiskotten, Dean of Syracuse University College of Medicine
Dr. Joseph C. Hinsey, Dean of Cornell University Medical College
Dr. Victor Johnson, Director of Mayo Foundation for Medical Education and Research
Dr. Dean F. Smiley, Secretary of the Association of American Medical Colleges
Dr. Donald G. Anderson, Secretary of the Council on Medical Education and Hospitals, American Medical Association.

The Committee has stated that the objectives of the study are "to evaluate the present programs and determine the future responsibilities of medical education in the broadest aspect for the purpose of (1) improving medical education to better meet the over-all needs of the American people for the prevention of disease, the restoration as far as possible to health of all those who suffer illness or injury, and the maintenance of the best standards of physical and mental health of all the people; (2) assessing the degree to which medical schools are meeting the needs of the country for physicians; (3) promoting the advancement of knowledge in the field of medical science; and (4) better informing the public concerning the nature, content, and purpose of medical education".

From the nature and scope of the present survey, it is safe to predict that changes in the educational patterns will result in all of the major fields of medical education. The advancement of scientific knowledge and the changing conditions of medical practice have brought into sharp focus a number of subjects which will require an adequate place in the medical curriculum. Included in this group is the subject of nuclear energy and its application to medical practice and research. Physical medicine and rehabilitation will also command the attention of medical educators, in view of the increased span of life and the associated problems of chronic and degenerative disease. Social and economic factors must likewise be taken into consideration in future planning, as well as new concepts in relation to mental health, nutrition, preventive medicine, and other subjects. It may also be anticipated that, in future years, the basic medical sciences will be more closely integrated with clinical medicine and that the position of the internship will be more clearly defined in its relationship to the clinical clerkship, residency training, and general practice. In view of the interrelationship and interdependence of the various components of medical education, we may also look forward to further changes in premedical education and in the graduate and post-graduate fields.

Since the meeting of your Association in Quebec, the Council on Medical Education and Hospitals has revised the Essentials of an Approved Internship and the Essentials of Approved Residencies and Fellowships. The latter will, within a short time, undergo further revision, however, in order to incorporate the changes that have recently occurred with the establishment of the American Board of Proctology and the expansion of physical medicine into the broader field of Physical Medicine and Rehabilitation. An American Board has also been established in Preventive Medicine and Public Health, thus increasing to eighteen the number of certifying boards approved by the Medical Council on Education and Hospitals.

The general, or mixed, residency classification, previously included in the standards for residency training, has been discontinued, and in its place the Council has adopted specific requirements for residencies in general practice. These are designed to meet the needs of medical graduates intending to enter general practice, and should preferably be organized as two-year programs, offering broad experience and training in the major fields of internal medicine, general surgery, obstetrics, pediatrics, and the ancillary services of pathology, radiology, and anaesthesiology. It is not anticipated that residencies in general practice should be accepted as fulfilling any of the requirements for specialty certification. To do so would defeat the main purpose of this program, which is to increase the number of well-trained general practitioners in this country and to induce more and more of the young physicians to enter the general practice of medicine.

The plan for the temporary approval of residencies in specialties, adopted as an emergency measure to meet the increased postwar demand for residency training, has been discontinued by joint action of the Council on Medical Education and Hospitals and the Advisory Board of Medical Specialties. The residencies approved on a temporary basis, as well as other educational services that have not been reviewed within the last two years, are now being evaluated by the inspection staff of the Council and a selected group of eleven regional inspectors. This survey has progressed rapidly, and will probably be completed by the end of 1949. To supplement the program of hospital inspection, the American Board of Radiology is planning to conduct a further survey of radiological residencies, in cooperation with the Council on Medical Education and Hospitals. The pattern for this type of study has already been established in the cooperative survey of orthopaedic residencies, conducted in 1947 by the Council, The American Orthopaedic Association, and The American Academy of Orthopaedic Surgeons.

In the field of specialty training, we find at the present time an increasing interest in the development of hospital affiliations. This trend is especially apparent in regional planning, and may in some areas involve a

considerable number of outlying community hospitals. The extension of educational services by affiliation is basically sound, provided that the affiliated assignments are closely integrated in the total teaching program and that adequate medical supervision is supplied, both at the clinical and the coordinating levels. It is recognized, also, that such a plan will increase the level of medical and hospital practice in the affiliated area and, on a regional basis, will be an effective means for the wider distribution of medical personnel. It is important, however, that, in the decentralization of educational activities, the teaching function should not at any time be subordinated to the service requirements of individual communities. To guard against overextension or serious dilution of educational effort, it is essential, therefore, that affiliated programs be carefully evaluated to ensure that all components are organized in full compliance with existing standards.

The availability of clinical material for teaching purposes is a problem that will be of increasing concern in future years, particularly as more and more patients may seek private care under the continued expansion of voluntary medical and hospital prepayment plans. While private patients are often utilized extensively for teaching, they do not, as a general rule, fulfill the educational needs in those fields where operative experience is essential to the completion of the training program. It may be necessary in the coming years, therefore, to increase the opportunities for preceptorial or associated practical training beyond the period of institutional assignments. To some extent this need is already apparent, and it should receive further consideration in order that adequate and acceptable supplementary training may be available.

The specialty fields are also concerned in many of the general, over-all problems in medical education related to the training and distribution of medical personnel (general practitioners and specialists); the integration and correlation of general and specialty practice; the adequacy of community medical services; cooperation and coordination in teaching; medical research; increased leadership in hospital organization medical service, and public health; flexibility in medical education; and the experimentation necessary to develop new and more effective methods of teaching. The answers to many of these questions will be evolved in the present survey, the influence of which on medical education will parallel the advances that followed the previous surveys of Abraham Flexner and H. G. Weiskotten. Medicine in America is at the highest point of development that has been reached anywhere in the world, yet today we are again spurred onward by the impelling force of progress, and in the survey which is now unfolding we can already sense the anticipation and exhilaration of new accomplishments ahead.

SUMMARY

By A. R. Shands, Jr., M.D.

You have been given a great deal of information this afternoon on the orthopaedic training program, from many different and varied sources. Your Chairman, in summary, can only comment on the most pertinent facts as he sees them. However, before summarizing he would like to thank each of the speakers for his part in this excellent symposium, especially Dr. Arestad from the American Medical Association.

Dr. Green has keynoted a few of the significant requirements for good training in stating that adequate material and stimulating teachers are the most important factors. I would reverse the order, for without the stimulus of the teaching, all training may be inadequate, irrespective of material.

Dr. Caldwell has brought out three important points in the teaching of basic science, namely (1) varied patients, (2) adequate facilities for study, and (3) sufficient time for the residents to correlate the findings in their patients on the basis of anatomy, pathology, biochemistry, et cetera. This third point should be emphasized, for most training is so filled with routine duties that time is definitely at a premium. All services should be planned so that the resident's time can be apportioned in a way which allows time to do the things which are not routine, time for reading and study, time for consultation with the laboratory chiefs, and time for discussions with the older staff men. This part of the training is essential; without it the full appreciation and proper correlation of clinical conditions cannot be had.

Dr. Speed spoke of special work in plastic surgery and he and Dr. Street mentioned neurosurgery. It is important that the residents have knowledge of these related fields of surgery and, if they can actually work on these services, as is done at the Campbell Clinic and Kennedy Veterans Hospital, the knowledge acquired should be satisfactory as well as lasting. Every possible opportunity should be given to the residents to learn and appreciate the problems involved in total rehabilitation, as is given in the Government hospitals. The return of the patient to society as a self-supporting individual, or as nearly self-supporting as is possible with his disability, is a definite responsibility of every orthopaedic surgeon. This is now being done best in Veterans Hospitals. The pattern should be copied in all large general and orthopaedic hospitals.

Whenever a service can plan on a junior-senior relationship of residents, as mentioned particularly by Dr. Green, it is wise to do so. The Senior immediately develops a sense of responsibility, as mentioned by Dr. Badgley, Dr. Speed, and others; and the Junior is instructed, as a rule, with more diligence and detail than if it were all done by the attending surgeon or chief-of-service.

The measuring and fitting of braces is too often left to the brace man. The young resident should be familiar with braces and their application. Dr. Thomas has stated that the relationship of the orthopaedic surgeon to the brace-maker should be as that of the architect to the builder. This is well expressed. I believe that on most services insufficient attention is given to instructing the resident in braces. A good knowledge of braces is important in dealing with all orthopaedic conditions, especially in the care of patients with cerebral palsy and infantile paralysis.

Dr. Smith has mentioned attending bone-tumor clinics. Few places are able to send their men to a Memorial Hospital, but still there are few institutions which do not have a tumor clinic in the vicinity which the orthopaedic residents could attend. Even if very little of the work in these clinics concerns orthopaedic tumors, the experience will be of distinct benefit. I like particularly what Dr. Smith has said about instruction in the technique and the positioning of patients for roentgenograms. This is something which few residents are taught, and there is certainly nothing more discouraging in the practice of orthopaedic surgery than poor roentgenograms, taken in the wrong position or at the wrong angle. Planned and scheduled conferences with the roentgenologist have been mentioned by several speakers, and should be a regular feature in all training programs.

I do not think that too much attention can be paid to teaching the residents how to speak while on their feet, as mentioned by Dr. Badgley, and the practical handling of patients—so important in private practice—as mentioned by Dr. Speed. Few services give special attention to these points. The correct method and form for the writing of papers should be included in the training. Each resident should be required to prepare a paper for publication during his training. Research problems should be encouraged, but not required. For some residents it will prove a great stimulus to later achievement; for others it will be lost time. The chief-of-service should evaluate as far as possible the investigative abilities of his resident staff and plan accordingly. Every service should require of the residents journal reading and preparation of a certain number of journal abstracts, and there should be regular journal-club meetings. In these conferences orthopaedic history should be included, as mentioned by Dr. Smith.

Before closing, a word should be said concerning the Government services. When the Veterans, Army, and Navy applied several years ago for approval of their newly established resident-training programs, it certainly was the belief of some of us that they would have great difficulty to develop services comparable to those of civilian institutions. What you have heard today from Dr. Street of the Veterans, Colonel Thompson of the Army, and Captain Barr of the Navy should allay all fears concerning the excellence of the training. They are not only measuring up to the standards of civilian training, but are giving a great deal more training in many fields, such as rehabilitation and the care of the paraplegic, than is being given in civilian institutions. The supervision of the work, with its volume and variety, is certainly adequate for good training. This information is most gratifying to those of us who have worked closely with the Surgeon Generals of the Army and Navy and the Chief Medical Director of the Veterans Administration during the last several years.

These are only a few of the pertinent facts from the discussions, as your Chairman sees them. Unfortunately, time does not permit elaborating further. As stated, no attempt should ever be made to standardize a pattern of training, but it is hoped that out of this Conference will come an improved method of training for every orthopaedic service engaged in the development and education of our orthopaedic surgeons of the future.

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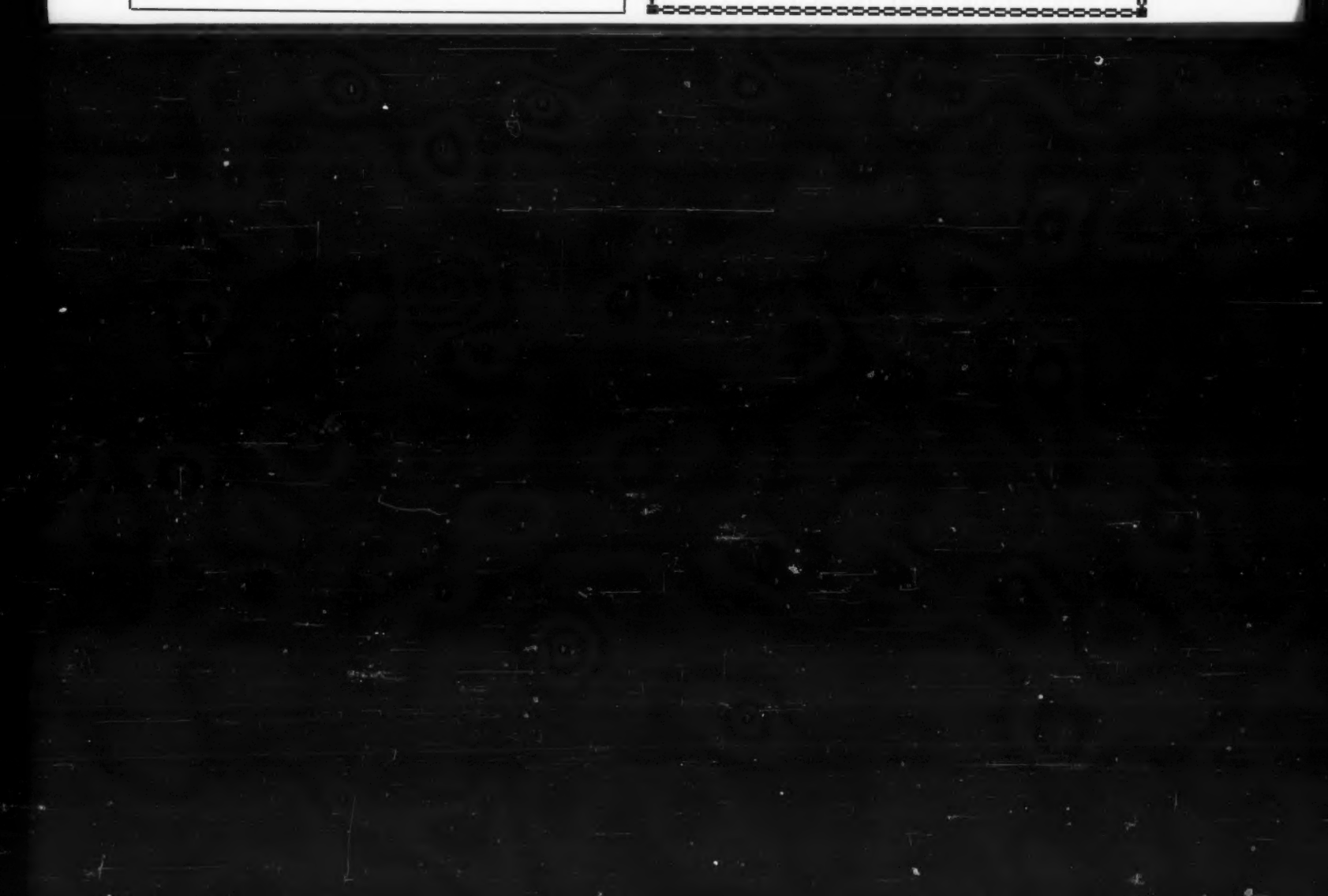

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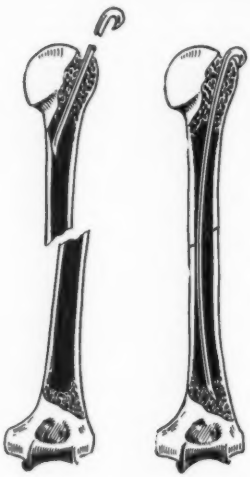

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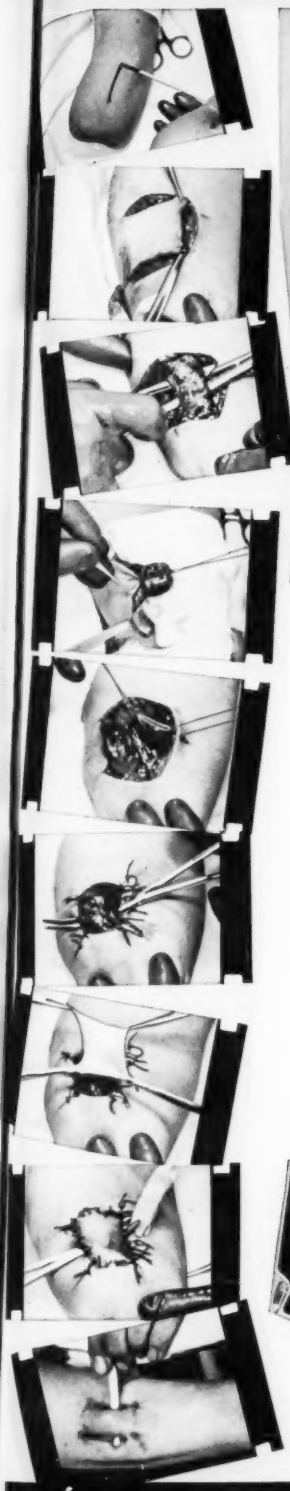

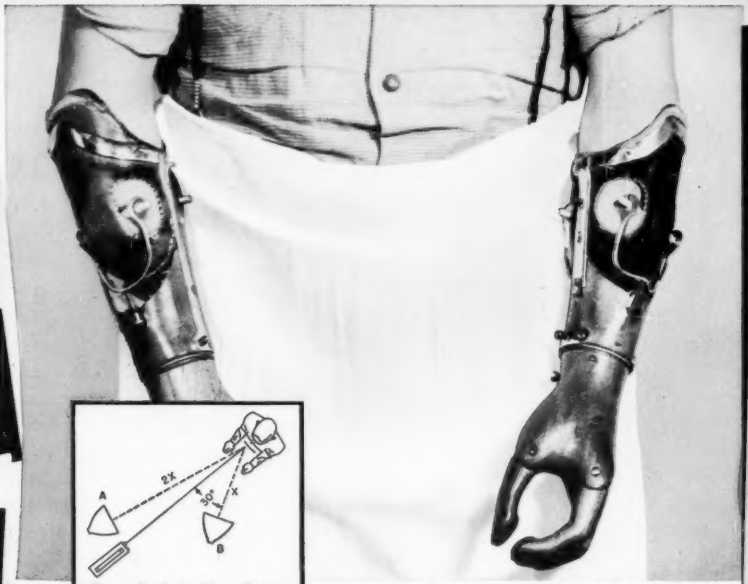

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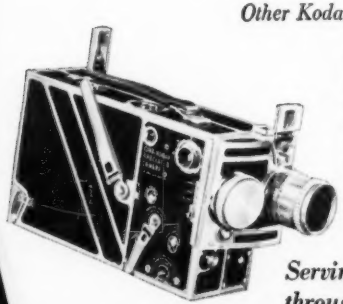

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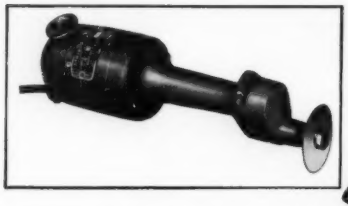

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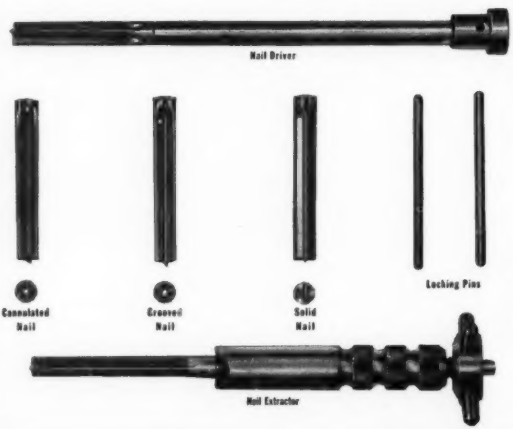

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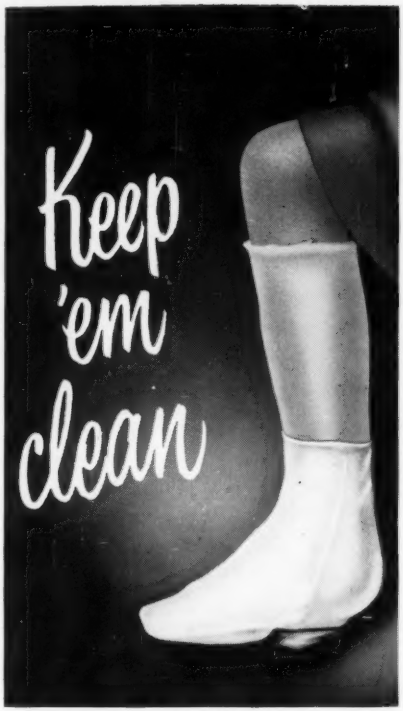

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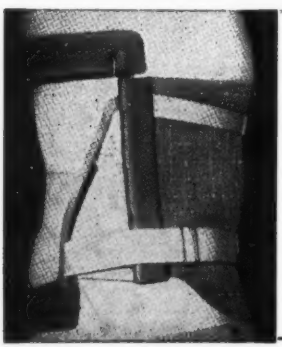

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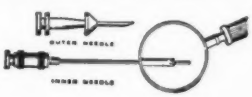

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ADDRESSES OF CONTRIBUTORS

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ORREN D. BAAB, M.D., New York Orthopaedic Hospital, 420 East 59th Street, New York 22, N. Y.

GEORGE H. DABBS, B.S., Morgantown, Kentucky.

THOMAS L. DELORME, M.D., Massachusetts General Hospital, Boston 14, Massachusetts.

G. W. N. EGGERS, M.D., University of Texas School of Medicine, Galveston, Texas.

WILLARD V. ERGENBRIGHT, M.D., Children's Hospital, Iowa City, Iowa.

JOSEPH A. FREIBERG, M.D., 707 Race Street, Cincinnati 2, Ohio.

J. ROSWELL GALLAGHER, M.D., Department of Health, Phillips Academy, Andover, Massachusetts.

ALEXANDER GIBSON, F.R.C.S. (Eng.), 601 Medical Arts Building, Winnipeg, Manitoba, Canada.

EVERETT J. GORDON, M.D., 2025 Eye Street, N.W., Washington 6, D. C.

SIDNEY GRANT, M.D., 6363 Wilshire Boulevard, Los Angeles, California.

WALTER A. GUNTHER, M.D., The Caldwell, Troy, New York.

JOHN H. HEINEN, JR., M.D., 950 East 59th Street, Chicago 37, Illinois.

M. BECKETT HOWORTH, M.D., 33 East 61st Street, New York 21, N. Y.

IRVING HYMAN, M.D., 109 Linwood Avenue, Buffalo 9, New York.

ALBERTO INCLÁN, M.D., 21 No. 456, Vedado, Habana, Cuba.

JULIAN E. JACOBS, M.D., 121 West Seventh Street, Charlotte 2, North Carolina.

ROBERT A. KAISER, M.D., 462 Grider Street, Buffalo 15, New York.

ROBERT A. KNIGHT, M.D., 869 Madison Avenue, Memphis 3, Tennessee.

FREDERICK J. KRUEGER, M.D., United States Marine Hospital, Staten Island, New York.

PIERRE LACROIX, M.D., Institut d'Anatomie, Université de Louvain, 28, Rue des Récollets, Louvain, Belgium.

F. WAYNE LEE, M.D., 314 Professional Building, Charlotte, North Carolina.

L. MAXWELL LOCKIE, M.D., 40 North Street, Buffalo 2, New York.

FREDERICK C. LOWRY, M.D., 312 West 15th Street, Austin, Texas.

HAROLD A. MASON, B.S., 1143 East 60th Street, Chicago, Illinois.

ARTHUR A. MICHELE, M.D., 166 Clinton Street, Brooklyn 2, New York.

ELMER MILCH, M.D., 40 North Street, Buffalo 2, New York.

IAN D. MURPHY, M.D., Hahnemann Hospital, Philadelphia, Pennsylvania.

BENJAMIN E. OBLETZ, M.D., 685 Delaware Avenue, Buffalo 9, New York.

DAVID R. OLIVER, M.D., 600 South Kingshighway, St. Louis 10, Missouri.

RALPH C. PETERSEN, M.D., 218 North Central Avenue, Glendale 3, California.

CHARLES M. POMERAT, Ph.D., University of Texas School of Medicine, Galveston, Texas.

GEORGE D. PURVIS, M.D., 869 Madison Avenue, Memphis 3, Tennessee.

FRED C. REYNOLDS, M.D., 4952 Maryland Avenue, St. Louis 8, Missouri.

WALTER SCOTT, M.D., 4759 Hollywood Boulevard, Hollywood 27, California.

THOMAS O. SHINDLER, M.D., University of Texas School of Medicine, Galveston, Texas.

ALAN DEFOREST SMITH, M.D., 1 East 63rd Street, New York 21, N. Y.

AUGUST W. SPITTLER, Colonel, M.C., Walter Reed General Hospital, Washington 12, D. C.

JOHS. SPOTOFT, M.D., Amtssygehuset, Kalundborg, Denmark.

LLOYD W. TAYLOR, Lieutenant Colonel, M.C., Madigan General Hospital, Fort Lewis, Washington.

GEORGE W. VAN GORDER, M.D., 262 Beacon Street, Boston 16, Massachusetts.

ARTHUR L. WATKINS, M.D., Massachusetts General Hospital, Boston 14, Massachusetts.

JAMES B. WEAVER, M.D., University of Kansas Medical Center, Kansas City 3, Kansas.

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